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GEOPHYSICS

A Journal of General and Applied Geophysics

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The Society of Exploration Geophysicists

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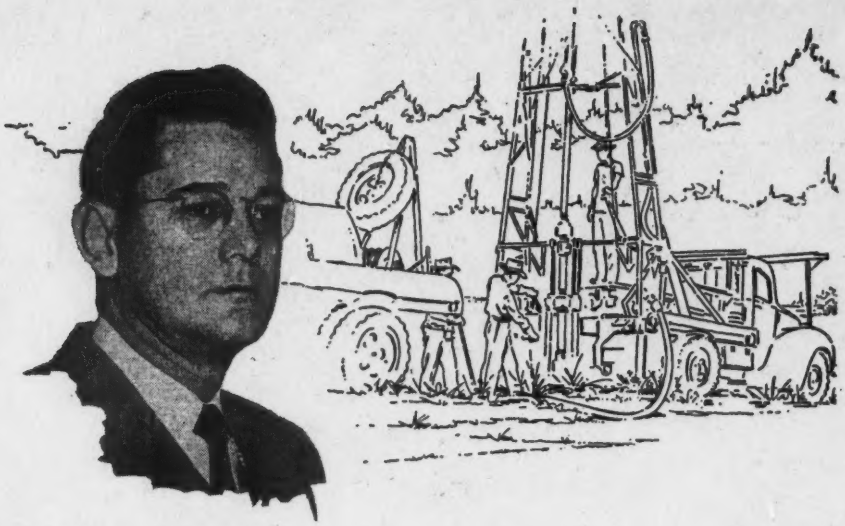

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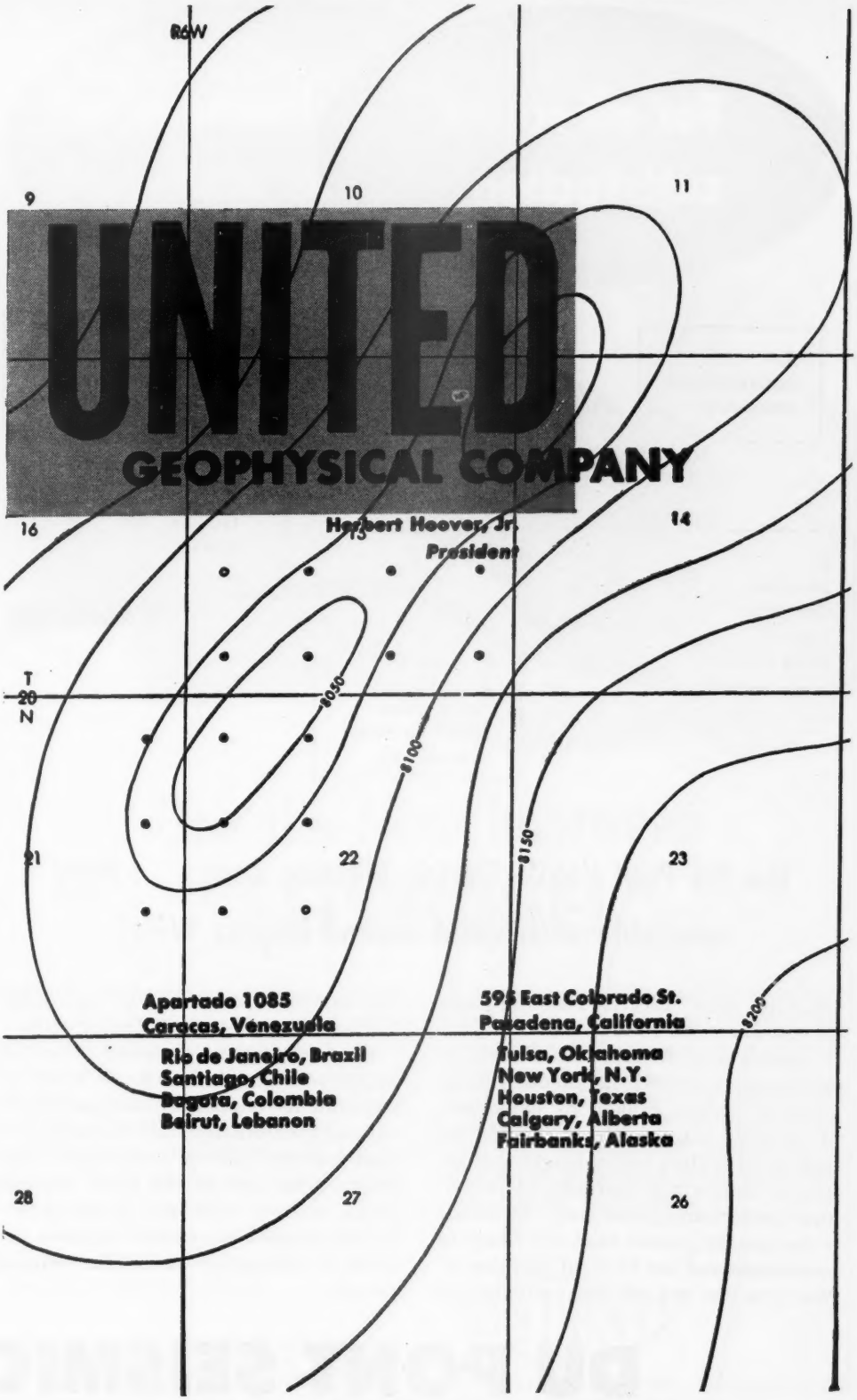

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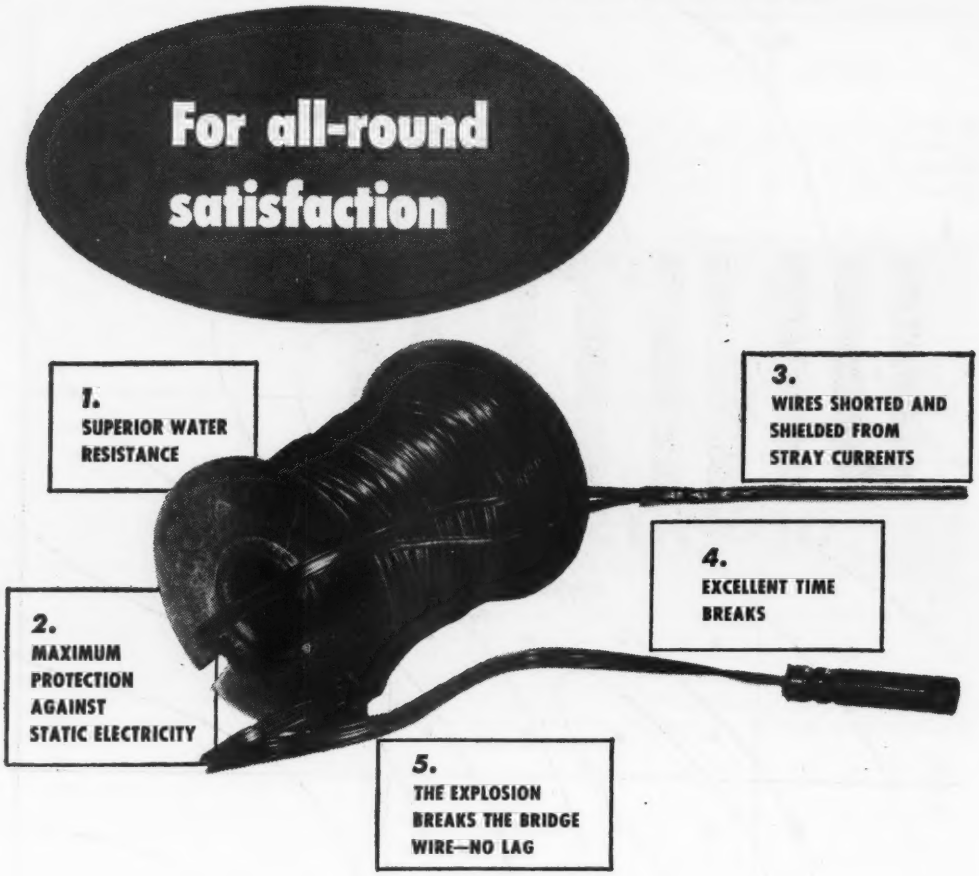

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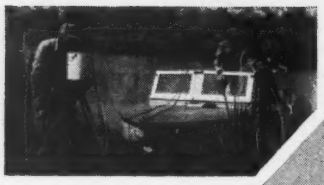

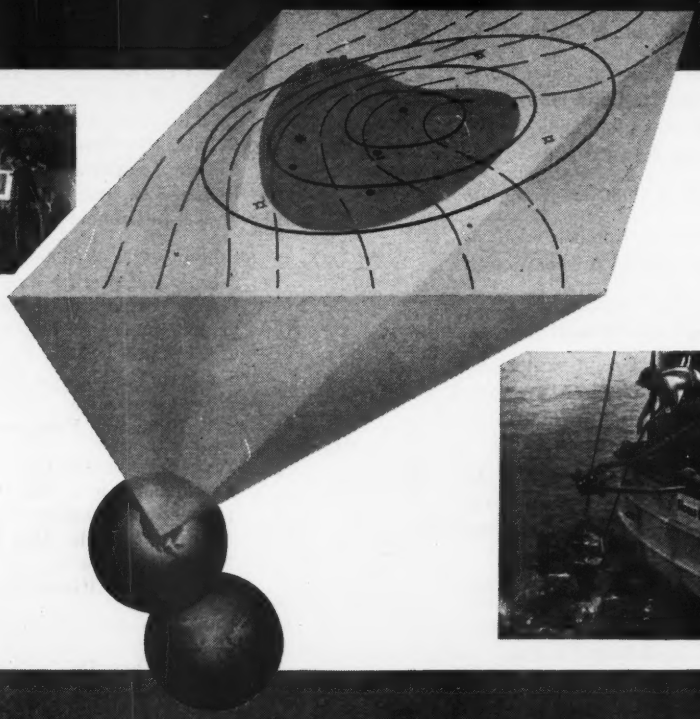

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A GRAPHICAL METHOD FOR THE INTERPRETATION OF REFRACTION PROFILE DATA*

M. M. SLOTNICK†

ABSTRACT

A graphical method for interpreting refraction profiles is presented by means of a complete solution of a numerical example.

INTRODUCTION

The usual methods of interpretation of refraction profile data are for the most part extremely cumbersome to handle and suffer from the fact that almost always they presume a far greater accuracy of the data than is justified. We propose to indicate a graphical method which has been used for many years, which is consistent with the accuracy of the data, and which has met with success in its application and results. The method can be mastered and used with ease once the basic concepts involved are grasped.

It is indeed a difficult matter to present in a single paper all possible, and all necessary, variations of the techniques involved. Thus, in order to outline the method in the most desirable fashion, we shall indicate, first the basic ideas and follow this up with the numerical solution of an actual profile, taken from our data. For presenting a paper in this pedagogic manner, we offer such apologies as are necessary with the explanation that we feel it is the easiest and best method of presentation.

We should also add that it is not our purpose to discuss necessary corrections for shot-hole depths, elevations and such other important matters in this paper. As a consequence, it is assumed that the data to be studied have all been corrected by any of the usual means and that the time-distance curves, as presented, form the resultant corrected data which are to be used.

It is also assumed that all the refraction profiles are reversed and, of course, that the data are consistent: namely, that the over-all reversed times are equal; that the intercepts of the sections of the time-distance curves of "adjacent" profiles with the common time-axes are equal, (assuming monoclines in the area

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around the shot-points). As is also known, changes in dip of beds between the ends of a profile can be detected by noting whether the intercepts of corresponding sections of the reversed time-distance curves with the time-axes at both ends of the profile are equal or not. A refraction time-distance graph is, at best, an approximation by straight lines and its interpretation therefore is an approximation to the factual situation.

Finally, "all the action," so to speak, is assumed to take place in the vertical plane through the line of the profile. Necessary corrections for the true plane, or planes, can be made after this first interpretation is completed.

FUNDAMENTAL RELATIONS

Among the basic relations necessary for our problem are these:

(a) that refraction across interfaces occurs in the manner associated with Snell's Law;

(b) that "complete" refraction along plane interfaces occurs at the so-called critical angle;

(c) that the emergence angle α of a wave coming to the surface of the earth, immediately under which, after low-velocity and weathering corrections have been made, the velocity is v_1, is connected with the time-distance curve, $t=t(x)$, by the relation

$$\sin \alpha = v_1(dt/dx). \tag{1}$$

Since we are assuming that our time-distance curve consists of straight line segments, the derivative, dt/dx, may be replaced by the ratio of the corresponding increments: $\Delta t/\Delta x$.

Single Dipping Interface.—Suppose that we have the reversed time-distance curves of Figure 1 emanating from the shot-points O and O'. The slopes of the first branches of each of these two time-distance curves are assumed equal, and, as is customary, we indicate the reciprocal of their common value by v_1. The reciprocal of the slope of the second part of the time-distance curve beginning at O we indicate by v_{2d}, whereas the corresponding quantity for the reverse time-distance curve is indicated by v_{2u}. Let us assume, too, that

$$v_{2u} > v_{2d}.$$

Let the over-all time of the refracted wave from O to O' be T and denote the velocity in the medium below the desired interface by v_2, which, of course, must be greater than v_1.

Our problem is two-fold: to find v_2 and to locate the interface. We proceed as follows:

From O' draw the line $O'A'$ whose angle with the vertical is α', where

$$\sin \alpha' = v_1(dt/dx)' = v_1/v_{2d}.$$

This is the direction of the emerging ray at O'. At O, similarly, draw the line OA whose angle with the vertical is α, where

$$\sin \alpha = v_1(dt/dx) = v_1/v_{2u}.$$

These two lines, OA and $O'A'$, are brought to intersection at Q. The angle included between them at Q is $\alpha+\alpha'$, which is indicated by 2θ, since it should be geometrically evident that it is twice the critical angle θ for v_1 and v_2. That is,

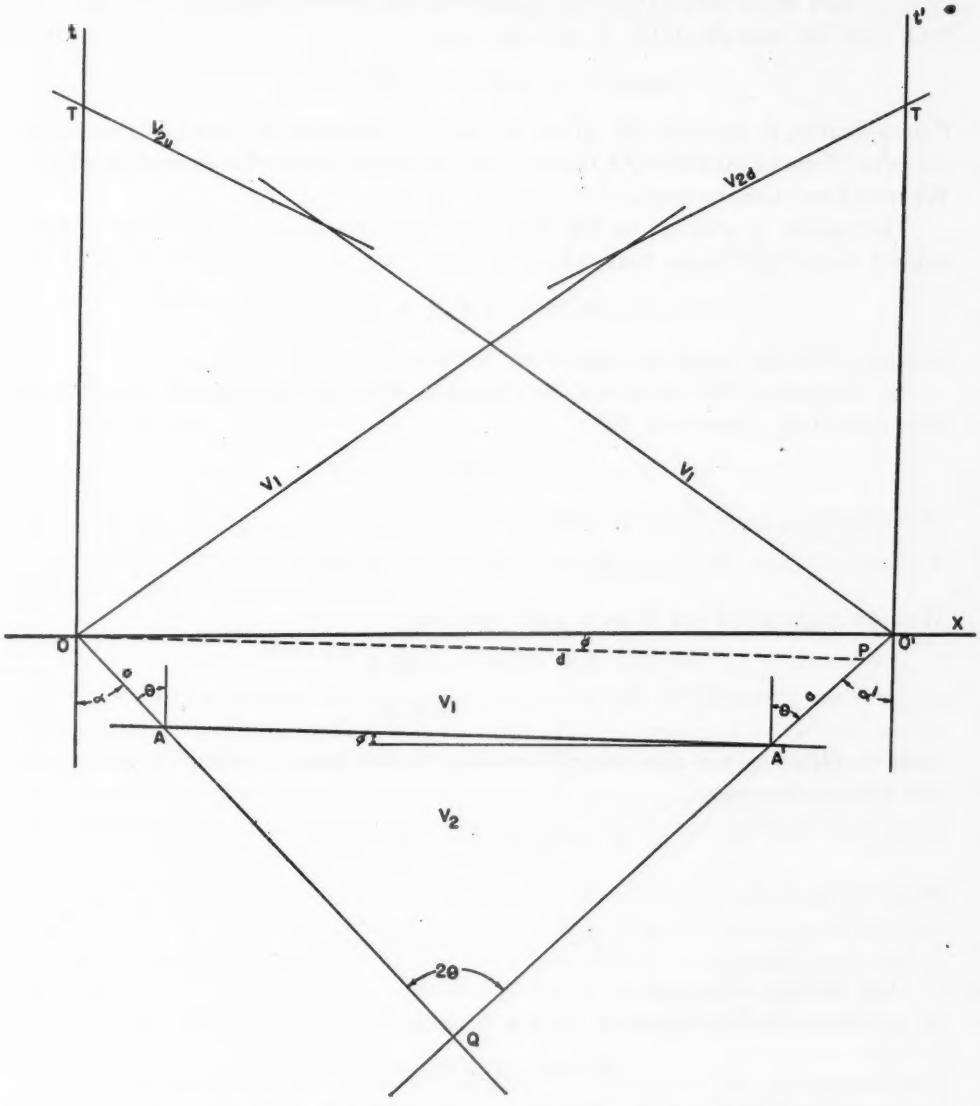

FIG. 1. Time-Distance Curve for Single Dipping Interface.

$$2\theta = \alpha + \alpha',$$

and

$$\sin \theta = v_1/v_2.$$

In fact, we compute v_2 from the relation

$$v_2 = v_1/\sin \theta = v_1/\sin (\alpha + \alpha')/2.$$

It is now to be noted that the position of the desired interface AA' must be such that the triangle AQA' is isosceles, since

$$\measuredangle OAA' = \measuredangle O'A'A = 90^\circ + \theta.$$

Consequently, if, on $O'Q$, the larger of the two distances OQ and OQ', we place the point P such that $QP = QO$, the line OP will be parallel to the desired interface. We note here that the angle of dip $\phi = (\alpha' - \alpha)/2$.

The points A and A' on OQ and $O'Q$ respectively are now to be located subject to the conditions that $OA = PA'$ and

$$OA/v_1 + AA'/v_2 + A'P/v_1 + PO'/v_1 = T,$$

in which T is the observed travel-time between O and O'.

By computing PO', or better, by scaling it off in the diagram, we readily find the "correction" time τ for PO':

$$\tau = PO'/v_1.$$

The remaining time, $T - \tau$ we indicate by t; i.e.,

$$t = OA/v_1 + AA'/v_2 + A'P/v_1.$$

We now replace $OA = A'P$ by a, and note that

$$\begin{aligned} AA' &= d - 2a \sin \theta \\ &= d - 2av_1/v_2. \end{aligned}$$

Here $d = OP$, which is also best obtained by scaling from the diagram. Thus, the last relation becomes

$$t = 2a/v_1 + (d - 2av_1/v_2)/v_2$$

and

$$a = (v_2t - d)/2(v_2/v_1 - v_1/v_2).$$

The method of procedure is now apparent:

1. Draw the line OQ at an angle α with the vertical, in which

$$\sin \alpha = v_1(dt/dx) = v_1/v_{2u}.$$

The value of v_1 is found from the first section of the time-distance curve through

O or O' and the value of $dt/dx = 1/v_{2u}$ is that of the slope of the second segment of the time-distance curve through O'.

2. Draw the line $O'Q$ at an angle α' with the vertical, in which

$$\sin \alpha' = v_1(dt/dx)' = v_1/v_{2d}.$$

The value of v_1 is the same as above and the value of $(dt/dx)' = 1/v_{2d}$ is that of the slope of the second section of the time-distance curve through O.

The angle of dip, then, is $\phi = (\alpha' - \alpha)/2$, and the critical angle for the interface is $\theta = (\alpha' + \alpha)/2$.

3. Find v_2 from the fact that

$$v_2 = v_1/\sin (\alpha + \alpha')/2.$$

4. Determine the point P so that QP equals QO, and compute

$$\tau = O'P/v_1,$$

in which $O'P$ is obtained by scaling.

5. Compute

$$t = T - \tau,$$

in which T is the travel-time from O to O'.

6. Compute

$$a = (v_2 t - d)/2(v_2/v_1 - v_1/v_2)$$

in which d is the (scaled-off) distance OP.

7. Find the points A and A', by scaling, so that $OA = PA' = a$. *The line AA' is the trace of the desired interface.*

THE DATA FOR THE NUMERICAL PROBLEM

We are now ready to discuss a numerical problem. In Figure 2 we have the "adjusted" data forming time-distance curves of a reversed refraction profile plotted in the usual manner. For the sake of clarity, only the information necessary for the solution is put into this figure and all the subsequent figures.* For readers interested in following all the details, it is recommended that they make their own drawings on proper coordinate paper.

The line-segments in Figure 2 forming the time-distance curves are those of "best fit" in the sense that the due attention was paid to the accuracy of the data and of the applied corrections and to the consideration of adjacent and nearby profiles.

We shall, in fact, go on the assumption that we already know from the ad-

* Although the succeeding figures were drawn as closely to scale as possible, the requirements of drafting, engraving and printing and warping of the paper all have their effects in distorting some of the figures.

jacent profiles and preceding work in the area that we must fit this solution into one for which the succession of velocities with depth is 1,700 m/sec, 2,100 m/sec, 3,250 m/sec, and 4,150 m/sec. However, an additional bed appears on this profile as is evidenced by the segments of the time-distance curve of Figure 2 with the apparent velocities of 4,350 m/sec and 6,400 m/sec. It shall be our purpose in the last part of the problem to arrive at the *true velocity of that bed* and its disposition.

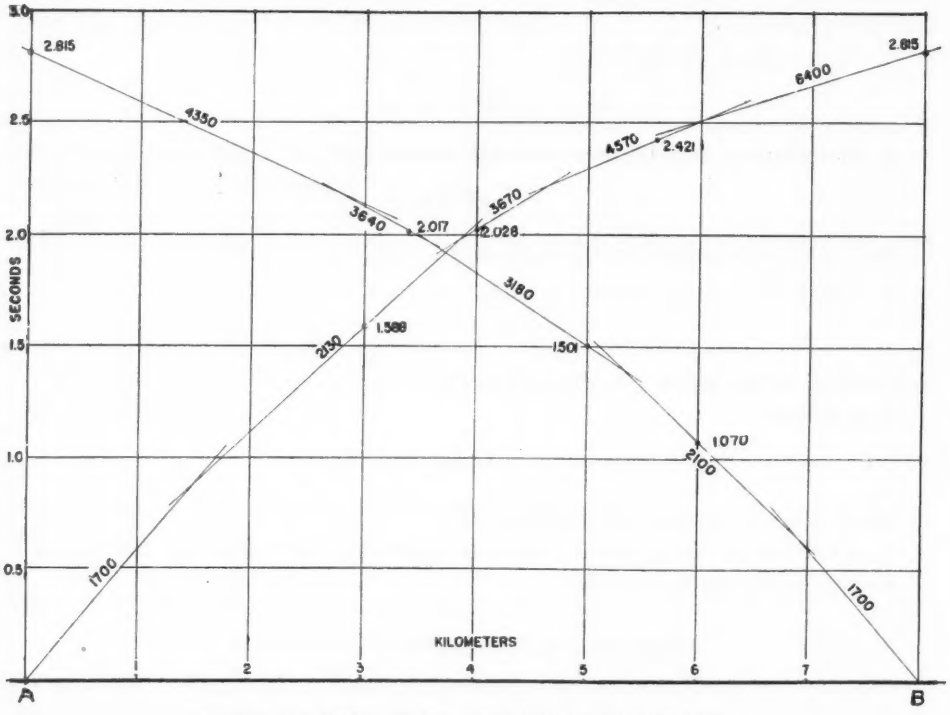

FIG. 2. Time-Distance Curve for the Numerical Problem.

The First Interface.—The discussion in this section pertains to Figure 3 for the solution of the first interface from the time-distance curve of Figure 2.

The segment of the time-distance curve starting at the left side labelled 2,130 quite obviously pertains to the bed whose velocity we know to be 2,100 m/sec.

Accordingly, we start by choosing an *arbitrary point* on this section of the curve. For the solution, we have chosen the point C at a distance of 3 kilometers from shot-point A for which the corresponding travel-time is 1.588 seconds.

Since we know the velocities involved to be 1,700 and 2,100 m/sec., the corresponding critical angle is θ, such that

$$\sin \theta = 1{,}700/2{,}100 = 0.8095;$$

i.e.,

$$\theta = 54^\circ.$$

At C, the emergence angle is α, in which

$$\sin \alpha = 1{,}700/2{,}130 = 0.798;$$

i.e.,

$$\alpha = 53^\circ.$$

This means that, at A

$$\beta = 2\theta - \alpha = 108^\circ - 53^\circ = 55^\circ.$$

With these preliminaries accomplished, we proceed as follows:

(i) Draw CD so that $\alpha = 54^\circ$.

(ii) Draw AD so that $\beta = 55^\circ$.

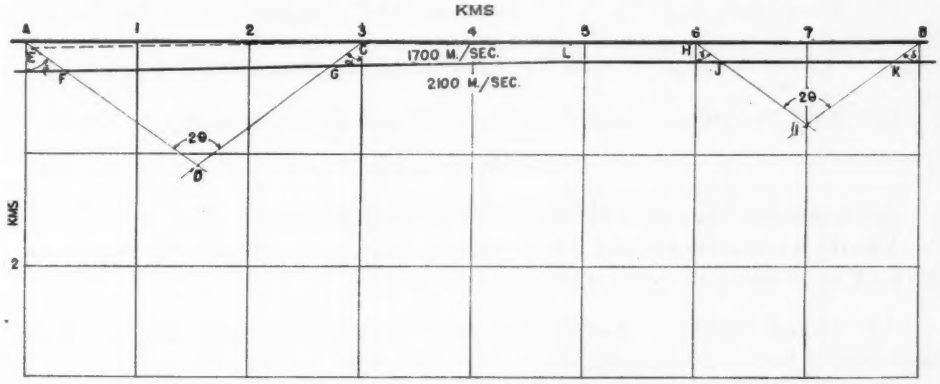

FIG. 3. Solution for the First Interface.

This, of course, leaves $\sphericalangle ADC = 108^\circ = 2\theta$, as it should be.

(iii) Find the point E, with dividers, so that $DE = DC$.

(iv) By scaling, we find $AE = 85$ m. The corresponding travel-time for this segment is

$$\tau = 85/1{,}700 = 0.050 \text{ sec.}$$

This leaves

$$t = 1.588 - 0.050 = 1.538 \text{ sec.}$$

for the rest of the path involved.

(v) Scale off $CE = 2{,}930$ m.

(vi) Compute, using relation (2), the quantity:

$$a = (2{,}100 \times 1.538 - 2{,}930)/2(2{,}100/1{,}700 - 1{,}700/2{,}100) = 350 \text{ m.}$$

(vii) Find the points G and F on CD and AD, respectively, so that

$$CG = EF = a = 350 \text{ m}.$$

(viii) Draw the line FG. *The line FG is the desired trace.* Its dip, with respect to the horizontal is $(\beta-\alpha)/2 = 1°$.

We now turn to the right-hand shot-point at B. Again we choose an arbitrary point: in this case, it is the point H at a distance of 2 kilometers from B and for which the travel-time is 1.070 sec., as shown in Figure 2.

Since the apparent velocity on this section is 2,100 m/sec, which is also the true velocity, there is no dip to the interface in this area.

The steps to be followed here are:

(i) Draw HI so that γ of Figure 3 is 54°, since

$$\sin \gamma = 1{,}700/2{,}100.$$

(ii) Draw BI so that δ of Figure 3 is 54°.

(iii) Since there is no dip to the interface here, compute a from relation (2):

$$a = (2{,}100 \times 1.070 - 2{,}000)/2(2{,}100/1{,}700 - 1{,}700/2{,}100) = 290 \text{ m}.$$

(iv) Find the points J and K on lines HI and BI, respectively, so that

$$HJ = BK = 290 \text{ m}.$$

(v) Draw the line JK. *The line JK is the desired trace.*

Finally we extend FG and JK to intersection at L and have the *broken line $FGLJK$ of Figure 3 the trace of the first interface.*

The Second Interface.—Let us first recall that we know the velocity of the next deeper bed to be 3,250 m/sec.

The related segment of the time-distance curve in Figure 2 indicates an apparent velocity of 3,670 m/sec. We choose an arbitrary point on this section which, for this solution, is the point C of Figure 4, at a distance of 4 kilometers from the shot-point A and for which the travel-time is 2.028 sec. as shown in Figure 2.

At C of Figure 4, the emergence angle α is obtained from the relation (1):

$$\sin \alpha = 1{,}700/3{,}670 = 0.463,$$

whence

$$\alpha = 27°30'.$$

(i) Draw CD at this angle with the vertical. The angle between CD and the *normal to ED* is μ which differs from α by the amount of dip of ED with respect to AC. This was found to be 1°. Thus

$$\mu = 27°30' + 1° = 28°30'.$$

According to Snell's Law, the ray CD, for which the angle of incidence with

the interface ED is $\mu = 28°30'$, refracts into the ray DH at an angle γ with the normal to ED such that

$$\sin \mu / \sin \gamma = 1{,}700/2{,}100.$$

Thus

$$\begin{aligned} \sin \gamma &= (2{,}100/1{,}700) \cdot \sin 28°30' \\ &= (2{,}100/1{,}700) \cdot 0.478 = 0.591. \end{aligned}$$

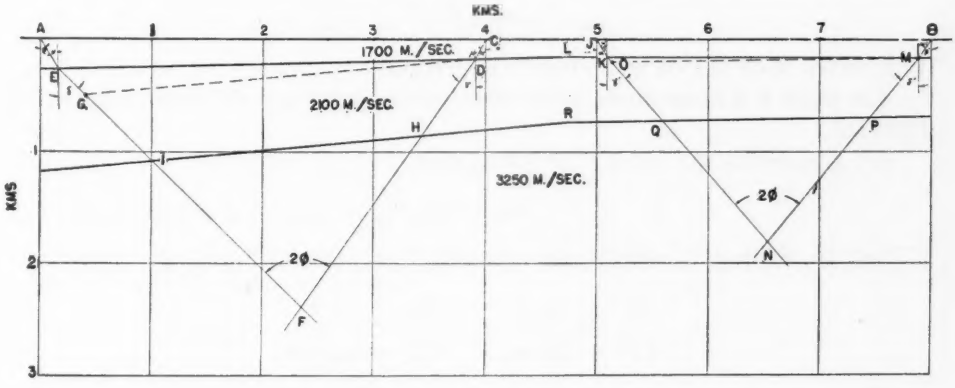

FIG. 4. Solution for the Second Interface.

whence

$$\gamma = 36°15'.$$

(ii) Draw the line DF from D so that $\gamma = 36°15'$.
The critical angle for the next interface is, of course, ϕ, where

$$\sin \phi = 2{,}100/3{,}250 = 0.646;$$

i.e.,

$$\phi = 40°15'.$$

We must therefore determine δ so that $\measuredangle EFD = 2\phi = 80°30'$. This leaves

$$\begin{aligned} \delta &= 2\phi - \gamma \\ &= 44°15'. \end{aligned}$$

We must still determine the position of the point E.
From Snell's Law:

$$\begin{aligned} \sin \nu &= (1{,}700/2{,}100) \cdot \sin \delta \\ &= (1{,}700/2{,}100) \cdot \sin 44°15' \\ &= 0.565. \end{aligned}$$

Thus

$$\nu = 34°30'.$$

The dip of ED with respect to AB is 1°. Whence, at A

$$\beta = \nu + 1° = 35°30'.$$

(iii) Draw AE at an emergence angle of $\beta = 35°30'$.

(iv) At E, so determined, draw EF so that

$$\delta = 44°15'.$$

This leaves $\sphericalangle EFD = 80°30'$, which was necessary.

The point F is determined as the intersection of DF and EF, and we note that $EF > DF$.

(v) Determine the point G of EF so that

$$FG = FD.$$

(vi) By scaling, determine the following distances (in Figure 4):

$$AE = 320 \text{ m.} \qquad EG = 370 \text{ m.}$$
$$CD = 220 \text{ m.} \qquad GD = 3{,}470 \text{ m.}$$

The time consumed for the parts AE and CD of the wave path is

$$(320 + 220)/1{,}700 = 0.318 \text{ sec.},$$

and the time consumed for the path EG is

$$370/2{,}100 = 0.176 \text{ sec.},$$

making a total of 0.494 sec. This leaves

$$t = 2.028 - 0.494$$
$$= 1.534 \text{ sec.}$$

for the rest of the path.

(vii) Accordingly, we use relation (2) again and compute

$$a = (3{,}250 \times 1.534 - 3{,}470)/2(3{,}250/2{,}100 - 2{,}100/3{,}250) = 840 \text{ m.}$$

(viii) Scale off the distances GI and DH equal to $a = 840$ m.

(ix) *The line IH is the desired interface.* Note that it dips at an angle of

$$(\delta - \gamma)/2 = 4°$$

with respect to the preceding interface, GD, of Figure 4.

We continue in like fashion from the other end of the profile.

Choose an arbitrary point J, (Figure 4), for which the travel-time is 1.501 sec. and for which the apparent velocity is 3,180 m/sec.

At J, angle α' is obtained from

$$\sin \alpha' = 1{,}700/3{,}180 = 0.534,$$

i.e.,

$$\alpha' = 32°15'.$$

(i) Draw JK so that $\alpha' = 32°15'$.

Since the interface KM is horizontal, no account for dip is necessary and we compute γ' from the fact that

$$\sin \gamma' = (2{,}100/1{,}700) \cdot \sin \alpha'$$
$$= 0.659;$$

i.e.,

$$\gamma' = 41°15'.$$

(ii) Draw KN so that $\gamma' = 41°15'$.

Since $\sphericalangle KNM$ must equal $2\phi = 80°30'$, it follows that angle $\delta' = 2\phi - \gamma' = 39°15'$. This, in turn, means that

$$\sin \nu' = (1{,}700/2{,}100) \cdot \sin \delta'$$
$$= 0.512,$$

and

$$\nu' = 30°45'.$$

Since the interface KM is horizontal, at B,

$$\beta' = \nu' = 30°45'.$$

Thus, we continue:

(iii) Draw BM so that $\beta' = 30°45'$.

(iv) Draw MN so that $\delta' = 39°15'$.

The point N is determined as the intersection of MN and KN, and we note that $KN > MN$.

(v) Determine the point O on KN so that $NO = NM$.

(vi) By scaling, we determine the following distances in Figure 4:

$$JK = 190 \text{ m.} \qquad KO = 65 \text{ m.}$$
$$BM = 205 \text{ m.} \qquad OM = 2{,}740 \text{ m.}$$

The time consumed for the parts JK and BM of the wave path is

$$(190 + 205)/1{,}700 = 0.232 \text{ sec.},$$

and the time consumed for the part KO is

$$65/2{,}100 = 0.031 \text{ sec.},$$

making a total of 0.263 sec. This leaves

$$t = 1.501 - 0.263 = 1.238 \text{ sec.}$$

for the rest of the path.

(vii) Accordingly, we use relation (2) again and compute

$$a = (3{,}250 \times 1.238 - 2{,}740)/2(3{,}250/2{,}100 - 2{,}100/3{,}250) = 710 \text{ m.}$$

(viii) Scale off the distances OQ and MP equal to $a = 710$ m.

(ix) *The line QP is the desired interface.* Note that it dips at an angle of

$$(\gamma' - \delta')/2 = 1^\circ$$

with respect to KM.

(x) Continue PQ and IH, previously obtained, to intersection at R. *The line IHRQP is the complete trace of the desired interface.*

The Third Interface.—For the third interface, we refer to Figure 5. The segments of the time-distance curve pertaining to this interface indicate apparent velocities of 4,570 m/sec. and 3,640 m/sec. and, as we assume we know, refer to a true velocity of 4,150 m/sec.

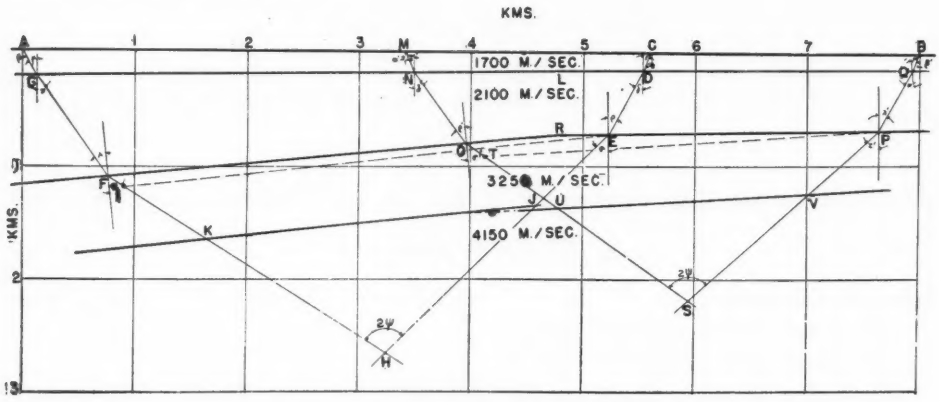

FIG. 5. Solution for the Third Interface.

Starting at the point C of Figure 5, for which the travel-time is 2.421 sec., we proceed in a manner similar to that pursued thus far:

$$\sin \alpha = 1{,}700/4{,}750 = 0.372,$$

$$\alpha = 21^\circ 45'.$$

Also, because QD is horizontal,

$$\gamma = \alpha = 21^\circ 45'.$$

Next,

$$\sin \delta = (2{,}100/1{,}700) \cdot \sin \alpha$$

$$= 0.459,$$

so that

$$\delta = 27°15'.$$

Now

$$\rho = \delta + 1° = 28°15'$$

because of the relative dip of 1° of EP with respect to OQ.
Continuing,

$$\sin \sigma = (3{,}250/2{,}100) \cdot \sin \rho$$
$$= 0.735,$$

from which

$$\sigma = 47°15'.$$

The critical angle for the two velocities of 3,250 m/sec. and 4,150 m/sec. is ψ where

$$\sin \psi = (3{,}250/4{,}150) = 0.783.$$

Thus

$$\psi = 51°30',$$

and

$$2\psi = 103°.$$

We first note that $\measuredangle PRF = 177°$. Since $\measuredangle PRF$, 2ψ, $90° - \sigma$ and $90° - \tau$ must add up to 360°, we find that

$$\tau = 52°45'.$$

To find λ, we proceed in similar fashion:

$$\sin \lambda = (2{,}100/3{,}250) \cdot \sin \tau$$
$$= 0.513,$$

and

$$\lambda = 30°45'.$$

Because of the dip of FO with respect to GN

$$\nu = \lambda + 4° = 34°45'.$$

Thus

$$\sin \mu = (1{,}700/2{,}100) \cdot \sin \nu$$
$$= 0.467$$

and

$$\mu = 27°30'.$$

Whence, at A,

$$\beta = \mu + 1^\circ$$
$$= 28^\circ 30'.$$

Knowing all the necessary angles for the construction, we can start at C and draw the line segments CD, DE and EH; then we can start at A and draw the line segments AG, GF and FH. The point H is determined as the intersection of EH and FH. The point I is placed so that $HI = HE$.

By scaling, we find that

$$AG + CD = 465 \text{ m.} \qquad FI = 145 \text{ m.}$$
$$GF + DE = 1{,}735 \text{ m.} \qquad IE = 4{,}360 \text{ m.}$$

Thus the time consumed for the path from A to I and from E to C is

$$465/1{,}700 + 1{,}735/2{,}100 + 145/3{,}250 = 1.155 \text{ sec.},$$

leaving

$$t = 2.421 - 1.155 = 1.266 \text{ sec.}$$

for the rest of the refracted path.
Accordingly, we compute

$$a = (4{,}150 \times 1.266 - 4{,}360)/2(4{,}150/3{,}250 - 3{,}250/4{,}150) = 905 \text{ m.}$$

The points K and J are determined by the fact that

$$IK = EJ = a = 905 \text{ m.}$$

and *the line JK is the desired trace of the desired interface.*

At the other end we start at M to which the travel-time from B is 2.017 sec. We compute the necessary angles as before and obtain:

$$\alpha' = 27^\circ 45'.$$
$$\gamma' = \alpha' - 1^\circ = 26^\circ 45'.$$
$$\delta' = 33^\circ 45'.$$
$$\rho' = 33^\circ 45' - 4^\circ = 29^\circ 45'.$$
$$\sigma' = 50^\circ 15'.$$
$$2\psi = 103^\circ.$$
$$\sphericalangle FRP = 177^\circ.$$
$$\tau' = 49^\circ 30'.$$
$$\lambda' = 29^\circ 30'.$$
$$\nu' = 29^\circ 30' - 1^\circ = 28^\circ 30'.$$
$$\mu' = 22^\circ 45'.$$
$$\beta' = 22^\circ 45'.$$

The line segments MN, NO, OS and BQ, QP and PS may now be drawn; the last of each group determining the point S as their intersection. The point T is such that $ST = SP$.

By scaling:

$$MN + BQ = 420 \text{ m.} \qquad OT = 200 \text{ m.}$$
$$NO + QP = 1{,}390 \text{ m.} \qquad TP = 3{,}520 \text{ m.}$$

Thus, for the parts of the wave path consisting of MN, NO, OT, PQ and QB, the time consumed is

$$420/1{,}700 + 1{,}390/2{,}100 + 200/3{,}250 = 0.971 \text{ sec.},$$

which leaves

$$t = 2.017 - 0.971 = 1.046 \text{ sec.}$$

for the rest of the path. We find that

$$a = (4{,}150 \times 1.046 - 3{,}520)/2(4{,}150/3{,}250 - 3{,}250/4{,}150) = 830 \text{ m.}$$

The points U and V are determined by making $TU = PV = a = 830$ m. and the line UV is the trace of the desired interface at this end.

Finally, KJ, previously determined, and UV are brought to intersection and the dotted segment of Figure 5 shows the degree of fit; which is well within expected limits of accuracy. A check will show that the displacement of the intersection of the trace with EH from J to the dotted section does no violence to the accuracy to be expected from the original data.

Thus, *KUV is accepted as the desired solution.*

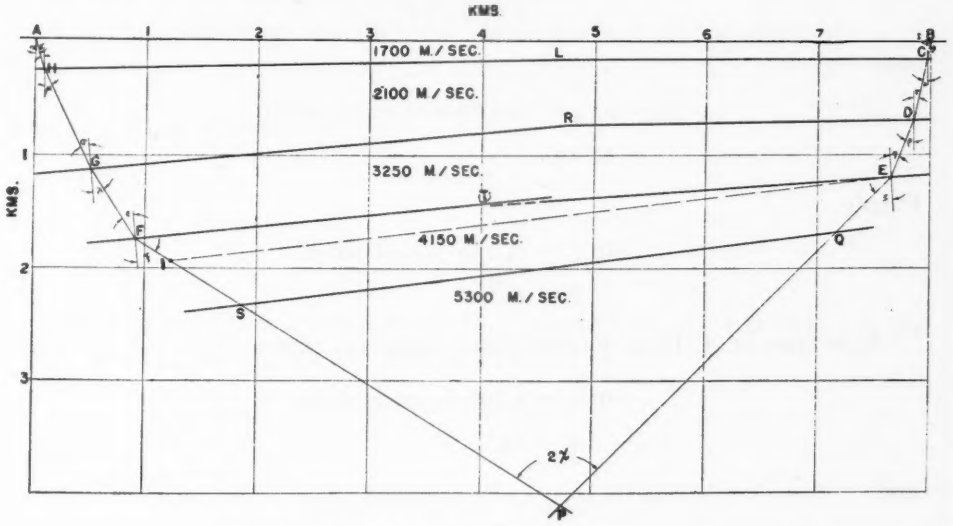

FIG. 6. Solution for the Last Interface and Velocity.

The Last Interface.—The total travel-time from A to B is equal to that from B to A and is 2.815 sec. The last segments of the time-distance curves indicate apparent velocities of 6,400 m/sec. and 4,350 m/sec.

We turn to Figure 6. At B, the emergence angle β is obtained from the fact that

$$\sin \beta = 1{,}700/6{,}400 = 0.266;$$

i.e.,

$$\beta = 15°30'.$$

Next

$$\delta = \beta = 15°30',$$

and

$$\sin \nu = (2{,}100/1{,}700) \cdot \sin \delta,$$

from which

$$\nu = 19°15'.$$

To continue,

$$\tau = \nu + 1° = 20°15' \text{ (because of relative dip)},$$

and

$$\sin \rho = (3{,}250/2{,}100) \cdot \sin \tau,$$

from which

$$\rho = 32°15',$$

and

$$\eta = \rho + 2° \text{ (because of relative dip)}$$
$$= 34°15'.$$

Finally

$$\sin \zeta = (4{,}150/3{,}250) \cdot \sin \eta.$$
$$\zeta = 46°.$$

Now start at A. Here the emergence angle is α, where

$$\sin \alpha = 1{,}700/4{,}350 = 0.391$$
$$\alpha = 23°$$

and

$$\gamma = \alpha - 1° = 22° \text{ (because of relative dip)}.$$

Thus

$$\sin \mu = (2{,}100/1{,}700) \cdot \sin \gamma,$$
$$\mu = 27^\circ 30',$$

and

$$\sigma = \mu - 4^\circ = 23^\circ 30' \text{ (because of relative dip).}$$

Next

$$\sin \lambda = (3{,}250/2{,}100) \cdot \sin \sigma,$$
$$\lambda = 38^\circ 15',$$

and

$$\epsilon = \lambda - 1^\circ \text{ (because of relative dip)}$$
$$= 37^\circ 15'.$$

Thus, finally,

$$\sin \quad = 4{,}150/3{,}250) \cdot \sin \epsilon,$$

and

$$\xi = 50^\circ 30'.$$

We now proceed to draw the line segments *BC*, *CD*, *DE* and *EP*, and the line segments *AH*, *HG*, *GF* and *FP* as in Figure 6. The point *P* is determined as the intersection of the last of each group. As in the Figure 6, we indicate $\measuredangle FPE$ by 2χ.

By scaling, determine $\measuredangle FTE = 175^\circ$. Since the sum of the angles:

$$\measuredangle FTE, \quad 2\chi, \quad 90^\circ - \zeta, \quad 90^\circ - \xi$$

must be 360°, it follows that

$$2\chi = 103^\circ 30'.$$

Thus

$$\chi = 51^\circ 45'.$$

The velocity of this last bed is then determined from the fact that χ is the critical angle between 4,150 and this velocity, v. That is,

$$\sin \chi = 4{,}150/v,$$

so that

$$v = 4{,}150/\sin 51^\circ 45' = 4{,}150/0.780$$
$$= 5{,}300 \text{ m/sec.}$$

to the nearest 50 m/sec. which is close enough for the data.

We have thus found the *last velocity* as part of the problem.

There remains only the disposition of the last interface; and, for this, we proceed as before:

Determine I by making $PI = PE$. By scaling,

$$AH + BC = 455 \text{ m.}$$
$$HG + CD = 1{,}580 \text{ m.}$$
$$GF + DE = 1{,}420 \text{ m.}$$
$$FI = 480 \text{ m.}$$

and

$$EI = 5{,}930 \text{ m.}$$

Thus,

$$455/1{,}700 + 1{,}580/2{,}100 + 1{,}420/3{,}250 + 480/4{,}150 = 1.573 \text{ sec.}$$

This leaves

$$t = 2.815 - 1.573 = 1.242 \text{ sec.}$$

as the time left for the lower parts of the wave path.
Accordingly

$$a = (5{,}300 \times 1.242 - 5{,}930)/2(5{,}300/4{,}150 - 4{,}140/5{,}300) = 660 \text{ m.}$$

The points S and Q are determined by making

$$IS = EQ = a = 660$$

and the line SQ is drawn *as the trace of the desired interface.* And this completes the problem.

ACKNOWLEDGMENT

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THE POULTER SEISMIC METHOD OF GEOPHYSICAL EXPLORATION*

THOS. C. POULTER†

ABSTRACT

The Poulter seismic method is outlined and an analysis is made of the frequency distribution of seismic energy from different sources. The effect of different sources upon the directivity of the energy in the ground and the improvement that can be obtained in signal-to-noise ratio is discussed. Three different methods are described for controlling the frequency of the seismic impulses being introduced into the ground and the resulting improvement in the quality of records is illustrated. The almost complete elimination of multiple reflections by the method is indicated.

INTRODUCTION

The material to be presented in this paper is the result of an extensive research program sponsored by the Institute of Inventive Research in San Antonio, Texas, for the purpose of developing and making available to the petroleum and geophysical industries the new seismic method of geophysical exploration which they have chosen to call the Poulter Seismic Method.

The method had its beginning in connection with the seismic survey of the Ross Shelf Ice made by the author while on the Second Byrd Antarctic Expedition (1947) and was being further developed at the Armour Research Foundation when the Institute of Inventive Research undertook its further development and commercialization. The research program during the past two years has been jointly conducted at the Southwest Research Institute and the Stanford Research Institute and their associated field laboratories.

In the early development, the Munroe shaped charge effect was utilized and later special explosive shapes not involving the Munroe effect. The present paper deals primarily with the techniques involved in the use of a pattern of charges detonated above the surface of the ground to generate a seismic pulse of controlled frequency to obtain seismic reflections from subsurface strata.

THE METHOD DEFINED

This method is an attempt to obtain an increased efficiency in the conversion of the energy of an explosion into useful seismic energy which has directive properties and which contains a minimum amount of random frequency and random phase relations. The research efforts of most of the geophysical departments of oil companies and geophysical contracting or instrument manufacturing companies has for the past twenty-five years been directed primarily toward better means of recording and interpreting that portion of the energy from underground explosions which reaches the surface of the ground at a number of points ranging

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in distance from a few feet to several miles from the shot point. Even more elaborate instrumentation is being developed for analyzing the data obtained in the form of complicated seismograms. In spite of all of this refinement for trying to convert the energy received into a less complicated record, very little attempt has been made to simplify or even control the uniformity of seismic energy being introduced into the ground. This method, therefore, is also an attempt to improve signal-to-noise ratio, not merely by trying to complete the partial filtering done by the earth on the continuous spectrum of primarily high-frequency energy radiation from a shot hole, but by applying a frequency control at the point of origin of the seismic wave.

Until we know how to convert a much greater portion of the energy of an explosion into useful seismic energy, we can at least attempt to generate only those frequencies which will best penetrate and be reflected from the structures being explored and produce a minimum of interfering energies. The mechanism by which a pattern of charges detonated in the air above the surface of the ground generates a seismic pulse with the major portion of its energy concentrated in a narrow frequency range, as well as the manner in which the desired frequency is obtained, will be discussed later.

FREQUENCY DISTRIBUTION OF SEISMIC ENERGY

Both theoretical and experimental studies of the distribution of the elastic wave energy near the shot point with respect to frequency and the type of material in which the charge was detonated were made by Dr. Joseph A. Sharpe (1942) prior to 1942. Dr. Sharpe states that of the three physical processes involved in seismic exploration; namely, the initiation of the seismic waves; their propagation, reflection, refraction, and dispersions; and the recording of some function of the motion of the surface, we possess the least satisfactory understanding of the initiation process.

Only a limited portion of the energy of a charge or pattern of charges detonated above the surface of the ground enters the ground and most of the energy from a shot hole remains below the surface of the ground. Therefore, for charges of equal energy, there is a great deal more energy entering the surrounding material in the form of elastic or inelastic wave motion from a shot hole charge than enters the ground from a pattern of charges detonated above the surface. An attempt has been made to study the frequency distribution of the energy in the two cases and to evaluate their effectiveness in obtaining useful information.

Instrumentation and Procedure

Due to the extremely broad frequency range involved, it is impractical to use the same instrumentation to cover the entire range and the following systems were employed.

The frequency range from 1,000 cps to 50,000 cps was recorded by photographing the trace on a cathode ray oscilloscope produced by a tourmaline crystal pressure gauge. The frequency range from 100 to 1,000 cps was obtained by

means of tourmaline crystal pressure pickup, a calibrated amplifier and galvanometer system. Some overlapping of these two ranges was obtained by the analysis of records obtained by the equipment described in Dr. Sharpe's (1942) paper.

The frequency range from 10 to 1,000 cps was obtained by means of a four-cycle geophone connected into a galvanometer through a resistance of 2,000 ohms. The peak frequency of the galvanometer was 140 cps and its characteristics were such that the combination gave nearly a flat response dropping off only 6 per cent at 100 cycles.

The records obtained from these different systems were converted to variable area records which were mounted on a lucite drum and driven past a slit in a photoelectric cell system. The signal thus produced was analyzed for frequency energy distribution by means of a harmonic wave analyzer.

Results

More than fifty records have been analyzed by this system and an attempt has been made in Figure 1 to show the distribution of energy with respect to frequency for charges fired in shot holes and in the air above the surface of the ground. The experimental conditions vary so widely for obtaining the complete frequency range for charges detonated in a shot hole and recorded by different systems that the different portions of the shot hole curves cannot be considered as strictly quantitative. However, it is believed that the information presented here is reasonably accurate below 1,000 cps, is somewhat less accurate between 1,000 and 5,000 cps, and should be considered a first approximation only above 5,000 cps.

These curves are plotted on an arbitrary but linear energy scale, and plotted to the same scale is a reproduction of the energy frequency curve from an air charge with its energy peaked at 30 cps. The dotted lines are similar curves peaked at 60 and at 20 cps.

No attempt has been made to plot the energy at the source and at the geophone to the same scale, but in both cases the energies from the two different sources are comparable and the frequency distributions of the energy at the geophone are from experimentally determined values.

In the case of the shot hole the frequency is distributed over a continuous spectrum ranging from ultrasonic to very low seismic frequencies with the major portion of its energy concentrated in a frequency range which is very much higher than will be transmitted to the geophone along the reflection path. The fact that the low frequencies have a higher velocity in the ground than the high frequencies produces a phase shift which gives the records the appearance of a much lower frequency. A frequency analysis of the reflections from different depths by means of the harmonic analysis shows an actual decrease in the frequency having the maximum energy as would be expected from the greater coefficient of absorption for the higher frequencies. Thus, it has long been recognized that reflections from deep horizons usually have a lower frequency than those from shallow horizons.

We have, in general, found that in the use of a pattern of charges detonated in the air in such a manner as to generate a seismic pulse having a slightly lower frequency than is normally produced by a shot hole charge in the same area, an improved record is frequently obtained on which there is little or no variation in frequency with depth.

The analysis of the energy at the geophones as represented in Figure 1 was accomplished by making a frequency energy distribution of the reflection portion of six representative traces on some reflection records, thus obtaining the total on cross-hatched and black area under the reflected energy curves. Another analysis

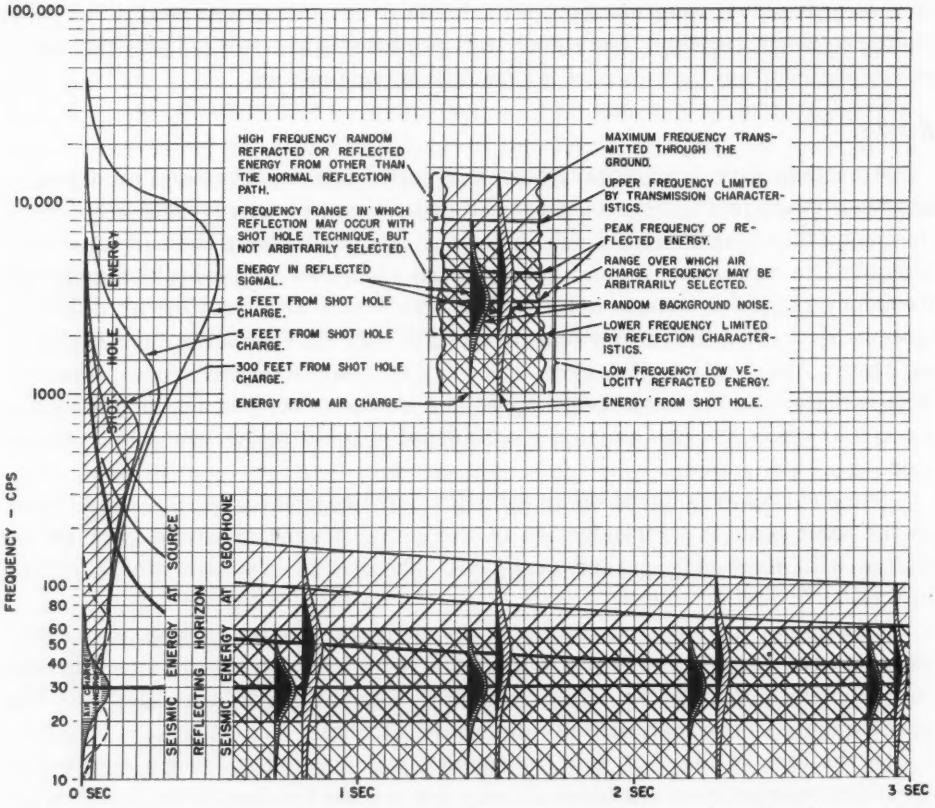

FIG. 1. Comparative energy-frequency distribution curves at the shot point and at the geophone for conventional shot hole technique as compared with a pattern of charges detonated above the surface of the ground.

was then made of the energy in the same six traces just preceding and following the reflection. This energy distribution curve was subtracted from the over-all energy curves of the reflection portion of the record thus leaving the black areas as reflected signal.

While it is realized that this is subject to certain errors, it is believed that they are minor and that the black areas represent within reasonable limits the total

reflected energy and the associated cross-hatched areas represent the random background noise. The ratio of these two areas can therefore be considered as a first approximation of signal-to-noise ratio.

If we could substitute for the shot hole a source which would accomplish a frequency discrimination by generating a pulse having primarily a narrow frequency range coinciding with the best transmission frequency of the ground, this energy would be transmitted with minimum attenuation. There is no upper limit to the seismic frequency that will be reflected from reflecting horizons, but rather the upper frequency limit is set by the frequency that will be transmitted through the overlying structures. In work on shelf ice and glaciers it is not uncommon to obtain 150-cycle reflections from subsurface strata through 1,200 feet of ice and 2,000 feet of water. The minimum frequency, however, is set by the reflecting horizon, and in general, the energy that will be reflected drops off very rapidly below 25 cycles. It is therefore possible that some *NR* areas are those in which these two limiting conditions approach one another or even overlap. The fact that the energy received at the geophone contains frequencies much lower than will be reflected and higher than will be transmitted along the reflected energy path is further proof that much of the background noise reaches the geophone by other than the reflected energy path.

DIRECTIVITY OF SEISMIC ENERGY FROM THE SHOT POINT AND SIGNAL-TO-NOISE RATIO

The spatial distribution of the seismic energy from the shot point is not onlv a major factor in determining the total energy in the reflected signal, but it is equally important in obtaining a good signal-to-noise ratio. The energy which produces seismic reflections comes almost exclusively from the energy that would be included in a vertical 90-degree cone whose apex coincides with the shot point

Instrumentation and Procedure

The instrumentation used for determining the distribution of energy in the ground at the shot point was the four-cycle geophone connected through a 2,000-ohm resistance to a galvanometer. This system had a flat response to within two per cent from 10 to 60 cps and dropped off only six per cent at 100 cps. In cases where the signal was too weak to be measured by this system, a calibrated amplifier system was used with geophones peaked at 15 cps and arranged to measure both vertical and horizontal components. On the glacier ice the geophones were set on the surface and the charges suspended in a large crevass in such a manner that the vertical wall of the crevass corresponded to the earth surface and the horizontal surface corresponds to a vertical plane. In the case of the shot hole charges, the geophones were placed in a vertical plane on a radius with the center of the charge at the center of the arc on which the geophones were placed. In the case of the charges detonated above the surface, the center of curvature on

which the geophones were placed was at the surface of the ground at the center of the pattern of charges.

Areas were selected with surface velocities ranging from 3,000 feet per second to more than 13,000 feet per second and in which this velocity did not change appreciably over the range of depths covered by the geophones. In other cases the distribution of energy passing a horizontal plane was measured. The latter is the most convenient method to use in the case of the charges detonated above the surface of the ground, because it only involves the drilling of a single geophone hole to the depth of the plane at which it is desired to make the measurements. The pattern of charges is then placed at different distances along the surface from a point directly over the geophone. The radial distance of the geophone or pressure pick-up from the center of the pattern area was large as compared to the over-all dimensions of the pattern.

Results and Discussion

These energy distribution measurements covered the range of surface material of solid ice, deep clays, gravel, and limestone. Figure 2 shows a polar coordinate diagram of the relative energy distribution of two typical conditions for both the shot hole and the air charge. No attempt has been made to plot the different curves on a comparable energy basis but merely to represent the distribution of energy for a single condition.

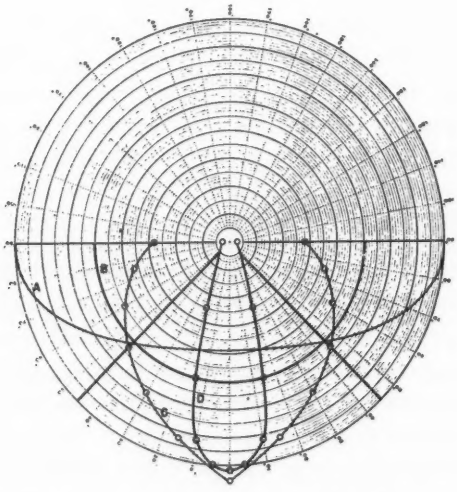

FIG. 2. Energy distribution from air pattern as compared to shot hole charges.
A.—Long vertical charge—15% of energy in 90° vertical cone.
B.—Concentrated charge—32% of energy in 90° vertical cone.
C.—Air pattern over low velocity weathered surface—85% of energy in 90° vertical cone.
D.—Air pattern over high velocity competent material at the surface—85% of energy in 30° vertical cone.

In the case of a shot hole charge which is very long as compared with its diameter, such as a 40-pound charge composed of eight $2\frac{1}{4}$ inch × 5 pound charges coupled together, much more energy is radiated normal to the charge than in line with it. It has long been recognized that in some areas where relatively large shot hole charges are required, it is necessary to spring the shot hole with one charge before it is possible to reduce the vertical dimensions of subsequent charges sufficient to produce a good reflection. Curve A in Figure 2 represents the distribution of energy for a long vertical charge and is the average of a number of closely similar curves obtained in a high velocity competent material.

There are probably two major factors contributing to the improvement in the quality of the reflection obtained by a concentrated shot hole charge as compared with the long vertical charge. First, the increase in the amount of energy directed downward, and second, the decrease in the energy directed horizontally which is the main source of energy contributing to the background noise. Hence, an improvement in signal-to-noise ratio. In the case of a concentrated charge in a shot hole, the energy distribution is essentially spherical as shown in Curve B of Figure 2.

In the case of shot hole charges, the important factors affecting the distribution of energy are the distribution of the charge in the hole and the condition of the hole. Successive records made with the same size charge in the same shot hole may be quite different not only with respect to all random energy but even the character of the reflections. However, in the case of successive records made with charges in air at the same shot point, the records are reproduced almost to the minutest detail. There is, however, a very marked difference in distribution of energy depending upon the material over which an air charge is detonated. Curve C in Figure 2 was obtained in a coarse gravel soil fill in the Santa Clara Valley and an almost identical distribution was obtained in the San Joaquin Valley, whereas a distribution as shown in Curve D in Figure 2 was obtained from a high surface velocity area of competent material in West Texas. An almost identical distribution was obtained on the solid ice of Taku Glacier in Alaska.

From an examination of a great many records it has generally been found that the greater the concentration of energy in a vertical direction the greater will be the signal-to-noise ratio. Most areas that are considered NR areas are so considered not because the seismic signal is attenuated very rapidly but rather because the signal-to-noise ratio is very unfavorable. In a personal communication from Dr. Joseph A. Sharpe he stated that a signal-to-noise ratio of 1.2 will give a record on which the reflections can be readily picked, whereas a signal-to-noise ratio of 0.8 is sufficiently unfavorable as to completely obscure any reflection. Such a condition is particularly well illustrated in a set of records taken in New Mexico and shown in Figure 3. The approximate signal-to-noise ratio of these records was obtained by the method previously described for the preparation of Figure 1.

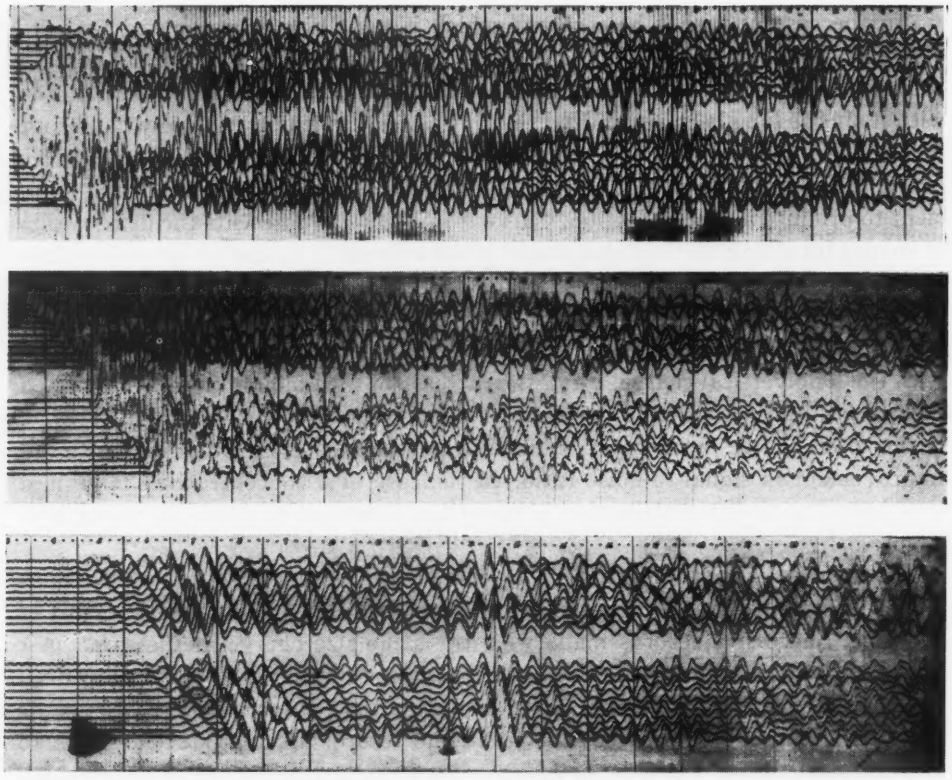

FIG. 3. Three records showing comparison of signal-to-noise ratios.
Top record—Background noise from shot in split spread record completely obscures reflection. Signal-to-noise ratio about 0.8.
Middle record—2,640-foot in-line offset shot hole reduces back-ground noise enough so that reflection can be picked. Signal-to-noise ratio about 1.0.
Bottom record—Air charge record shows greatly improved signal-to-noise ratio and outstanding reflection. Signal-to-noise ratio about 2.0.

Record (A) is a conventional split spread using a 10-foot long, 25-pound charge in a 200-foot shot hole. Record (B) was a 14-foot long, 35-pound charge at 220 feet taken at the same shot point location, except that the spread was moved to an in-line offset using the same 115-foot geophone spacing, but with the closest geophone 2,640 feet from the shot point. Record (C) was taken using the same shot point and spread location as (B) except that a pattern of seven 5-pound charges was substituted for the shot hole charge.

In record (A) the signal-to-noise ratio was so unfavorable that the reflection was completely obscured. However, by offsetting the shot hole, the background noise has been reduced to the point that a usable reflection was obtained in spite of the vertical height of the charge. In the case of the air pattern, the background noise was almost completely eliminated. The conditions indicated in Figure 2

are further illustrated in that the main reflection in record (C) contains more energy than it does in (B), whereas the first arrivals in record (B) contain more than one hundred times the corresponding energy contained in record (C). This further explains the improvement in quality of the reflections frequently obtained by an air charge as compared with a hole shot and the relatively weak refracted energies obtained by air charges as compared with shot holes.

FILTERING

Because of the large amount of background noise in the energy being received at the geophone in the conventional shot hole method, it is frequently necessary to use special filtering techniques in order to obtain a usable reflected signal. It is apparent from Figure 1 that the filtering with the Poulter method should be quite different than it is with the conventional shot hole technique. This is clearly illustrated in the three records shown in Figure 4, which were all taken at the same shot point location on a prospect in West Texas where four 24-hour spudder tours and two rotary drills were required for one seismic crew.

Record (A) was taken with a 50-pound charge in a 270-foot shot hole, using a filter setting that had been determined optimum after one month's operation

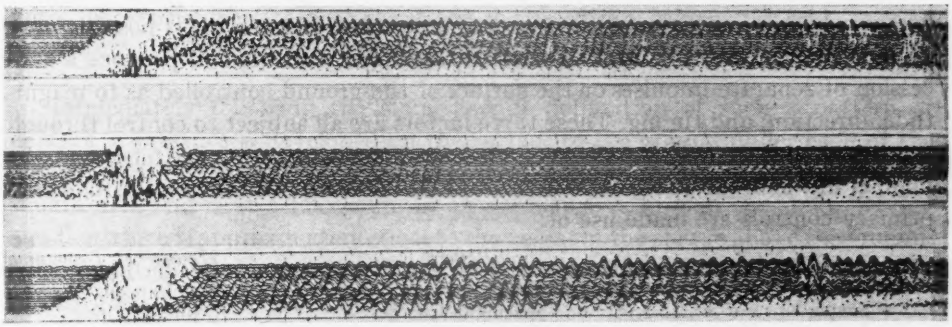

FIG. 4. Three records showing effect of conventional and broad filter setting on record quality.
Top record—Hole shot, 50 pounds at 270 feet, using optimum filter setting for shot hole record.
Middle record—Air shot, 70 pounds, using same filter setting as above.
Bottom record—Air shot, 65 pounds, using very broad filter setting.

on the prospect. For Record (B) the filter setting remained the same, but an air pattern containing a total of 70 pounds was substituted for the hole shot.

The filter setting was then opened up so as to pass all frequencies from 10 to 120 cycles and record (C) was obtained. The improvement of record (C) over (A) and (B) is probably due to three major factors. First, a signal was generated which had appreciably greater energy in a frequency range that would be readily transmitted. Second, the quantity of random background noise was appreciably reduced, and third, the wider filter setting permitted the free transmission of the signal whose signal-to-noise ratio was favorable. While extending the filter setting

on the low frequency side probably had more to do with improving the character of the reflections than did the extension on the high frequency end, it was most likely the high frequency extension that improved the character of the first breaks.

The pattern used in obtaining these records was one which generated a frequency a little lower than that transmitted from the shot hole. Two things have caused more tests of the method to fail than any other factors, they are the selection of a pattern whose frequency characteristics were not suited to the area and then superimposing on this a third frequency discrimination in the recording equipment instead of using an extremely broad frequency response system. Although a higher frequency record is frequently preferred from the standpoint of resolution, a lower frequency record, faithfully recorded, will give better resolution than a highly-filtered high-frequency record.

METHODS OF FREQUENCY CONTROL

The frequency of the seismic pulse being generated by a single charge or pattern of charges detonated above the surface of the ground may be controlled in a number of different ways. A pattern of charges suspended above the surface of the ground can be detonated in such a manner as to generate a pulse of seismic energy which is concentrated in a narrow frequency range. This is possible only because these charges can be so selected, arranged, and fired to produce a succession of separate impulses on the surface of the ground controlled as to magnitude, direction, and timing. These three factors are all subject to control through the proper selection of the charges, their arrangement into a pattern, and the manner in which the charges are detonated. In effecting this control, the following primary controls are made use of:

Charge	*Pattern*	*Manner of Detonation*
Size	Type	Simultaneous
Shape	Spacing of Charges	Sequence Firing
Detonation Rate	Height of Charges	
Location of Cap	Number of Charges	
Shielding of Charge		

The manner in which each of these primary controls is used will be discussed later.

Reflection Shock Wave Method of Frequency Control

For the best results the charges are positioned at about 8 feet above the surface of the ground in a 7- or 13-charge pattern (Figs. 5a and 5b). The cap is placed in the middle of the stick of explosive and all caps connected in series so as to obtain simultaneous detonation of all charges. In certain areas a straight-line pattern (Fig. 5c) is very effective. The charges are mounted on telescoping stakes which will permit the adjustment of the height of the charges above the ground, and the charges are supported on top of the stakes by some expendable or indestructible device. One commonly used device shown in Figure 5d is a paper

tube or a block of wood with a hole drilled in it to fit the top of the stake. A piece of wooden dowel stock, sharpened on the upper end, on which the charge is impaled is fitted into the other end. Another is a block of wood or other material (Fig. 5e) having a cross section such that it fits into the paper tube coupler on the stick of explosive. This block must contain no voids, such as an extension of the drilled hole, which can form a jet effect and damage the top end of the stake. There should also be no metal parts around the charge which could result in hazardous high-velocity fragments and possible grass fires.

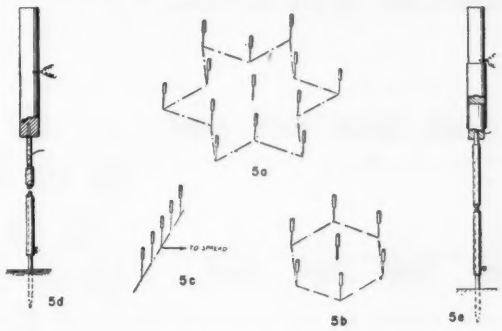

FIG. 5. Telescoping stakes for supporting charges on expendable or indestructible block, 5e, or expendable tube and pin, 5d, and arrangement of charges in pattern.

Immediately following the simultaneous detonation of such a pattern of charges, a pressure is developed on the surface of the ground under each of the charges. The magnitude of this pressure may be as much as 100 pounds per square inch and is at a maximum in an annular area around the stake, having a radius which is approximately equal to the height of the charge above the ground. The magnitude of this pressure drops off only slightly from this annular area in toward the stake, but drops off quite rapidly outwardly from that annular area. Figure 6 shows the essential steps in generating seismic energy having a limited frequency range by the shock wave reflection technique.

The detonation of these charges therefore starts a seismic wave front down into the ground under each of the charges. A vertical cross section of this action is shown in Figure 6a, and a plan view in Figure 6c. As these wave fronts advance downward into the ground, they spread out and merge together into a continuous circular section of a flat wave front. Then at a short time interval later the shock waves from adjacent charges meet midway between the charges (Fig. 6b). The reflection of these shock waves as they meet produces a second pressure on the ground which is equal in magnitude to that produced on the circular area under the charges. This pressure, however, instead of being distributed over circular areas, is applied over a grid pattern, as shown in Figure 6d.

As this wave front advances downward, it also spreads out into a continuous circular section of a flat wave front. The time interval between the time that

these two successive wave fronts are initiated at the surface of the ground is therefore determined by a number of factors, the most important of which is the horizontal spacing between the charges. The fact that the shock waves meet directly between adjacent charges a little earlier than they do at a point equidistant from three charges has a tendency to slightly broaden the peak frequency produced by the pattern. There are, of course, certain overlapping and cancellation effects in the immediate pattern area, but a major portion of the energy is directed down into the ground and is comparatively free from the broad band of frequency so characteristic of the shot hole.

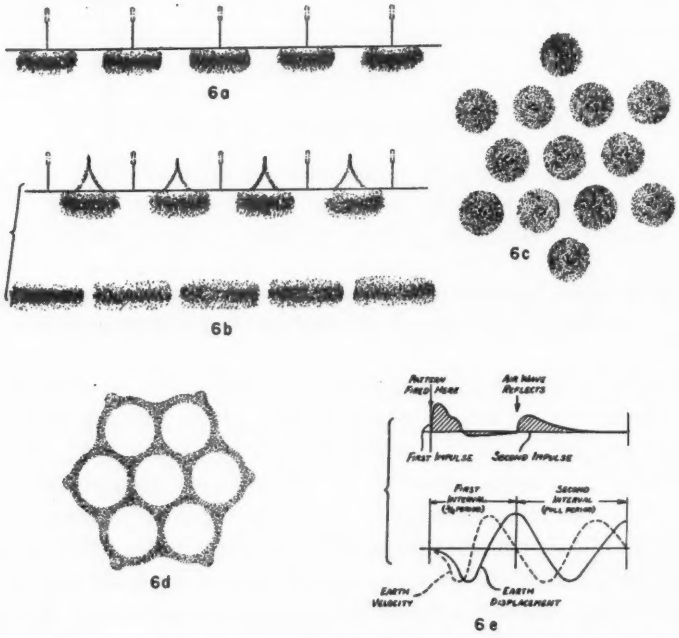

FIG. 6. The origin of seismic frequency by reflection shock waves. The initial multiple seismic wave fronts, 6a, followed by second wave front, 6b, shown in plan view, 6c and 6d, respectively. This properly timed sequence of positive, negative and positive pressure at the surface of the ground, 6e, generates a seismic pulse of controlled frequency.

The resultant earth transient consists of about two cycles and has the major portion of its energy concentrated in a narrow frequency range. The frequency which is generated is independent of whether a 3-, 7- or 13-charge pattern is used, provided that the arrangement of the individual charges in the pattern with respect to the adjacent charges remains unchanged. The frequency of the seismic energy which is introduced into the ground will, however, not correspond exactly to the difference in time of application of the pressure directly under the charges

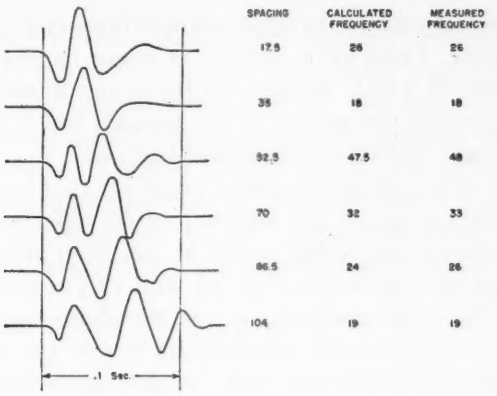

FIG. 7. Tracing of seismic pulses produced by pattern of 2½-inch×5 lb. charges 8 feet high. Frequency controlled by reflection shock waves for large spacing and pressure pulse for small spacings.

and that on the grid midway between the charges, but instead will be a somewhat lower frequency. The reason for this will be clear if the pressure-time cycle, the earth velocity, and the displacement curve are examined (Fig. 6e). If the earth particles are starting from rest and are being set into motion at approximately a fixed frequency, the time required for a particle to be displaced from its rest position to its first maximum displacement is only one-fourth of the cycle time, with half a cycle time being required for it to go from this maximum to its maximum displacement in the opposite direction. From the time of application

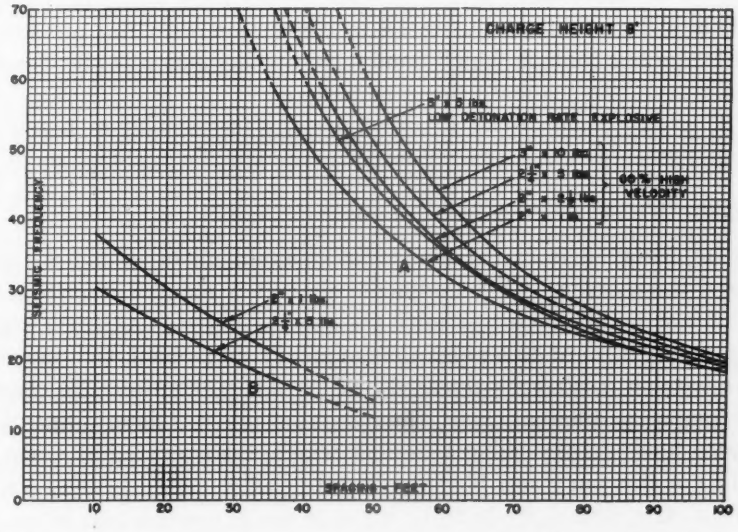

FIG. 8. Variation of seismic frequency for 7- or 13-charge pattern of 2½-inch×5 lb. charges mounted 8 feet high. At close spacing the pressure pulse dominates the frequency.

of the first downward impulse to the application of the second, is therefore, three-fourths of a cycle time. There are a number of minor factors which combine to determine the extent to which the seismic frequency differs from that of the application of forces upon the surface of the ground, but it will, in general, be lower by a ratio of only slightly less than four to three.

For the purpose of recording the seismic transient that is produced by a pattern of $2\frac{1}{2}$-inch$\times$5 lb. charges, 8 feet high and at six different spacings, a group of geophones connected in series was buried 20 feet deep under the pattern area and pattern spacings of 104, 86.5, 69, 52, 35, and 17.5 feet were used. Figure 7 shows a tracing of the seismogram for each of the above spacings and also lists the calculated frequency as read from Figure 8 and the peak frequency as measured by the harmonic wave analyzer. The geophones used for making these seismograms had natural frequencies of four cycles and were connected through a resistance directly to the galvanometer. The system had a flat response to within 2 per cent between 10 and 40 cycles and was only down 6 per cent at 100 cycles. The geophones had about 6 inches of dirt tamped over them in the holes and the top of the holes were covered over first with a board and then with loose dirt to prevent any air-borne energy from reaching the geophones. For 20-foot depths the geophones were located at horizontal distances from the charges equal to one-fourth the spacing between charges. However, comparable results were obtained with single geophones at a depth of 250 feet and independent of its location under the pattern area.

The group "A" curves of Figure 8 represent the theoretical frequencies calculated on the basis of the seismic frequency, being three-fourths the frequency represented by the shock wave arrival times at points under and midway between charges. This will be further illustrated in connection with the pressure pulse method of frequency control, which dominates the frequency at the closer spacings, and again in the sequence firing technique.

The "B" group of curves of Figure 8 are the frequencies as based on the pressure pulse method of frequency control as the spacing becomes small.

Pressure Pulse Method of Frequency Control

It will be observed from the above data that if all other factors are held constant and the spacing between adjacent charges is reduced, the frequency of the seismic pulse will be increased until the spacing between adjacent charges is approximately 35 feet. At this point the frequency drops back to a lower value, and as the spacing is further decreased, the frequency continues to change but through a somewhat different cycle. The reason for this was determined by means of high-speed photography using a camera which was operated at 3,000 frames per second. For this purpose a black and white grid was used in the background which permitted a careful study to be made of the expansion and interaction of the shock waves from adjacent charges. Such a high-speed motion picture was taken of the interaction of the shock waves from a group of $2\frac{1}{4}$-inch$\times$5 lb. charges spaced at 20-foot intervals and a tracing of these is shown in Figure 9a.

It will be seen that the shock wave velocity normal to the axis of the cylindrical charge fired with a cap at the middle is appreciably higher than it is along the axis. If the charges are spaced relatively close together, the individual shock waves merge to form an almost continuous envelope of the pattern area by the time they have reached the ground. Thus, instead of starting separate seismic waves down into the ground under each charge, a pressure is developed over the entire pattern area almost simultaneously. Then, due to the expansion of the gaseous products of the explosion in the pattern area, the air surrounding the

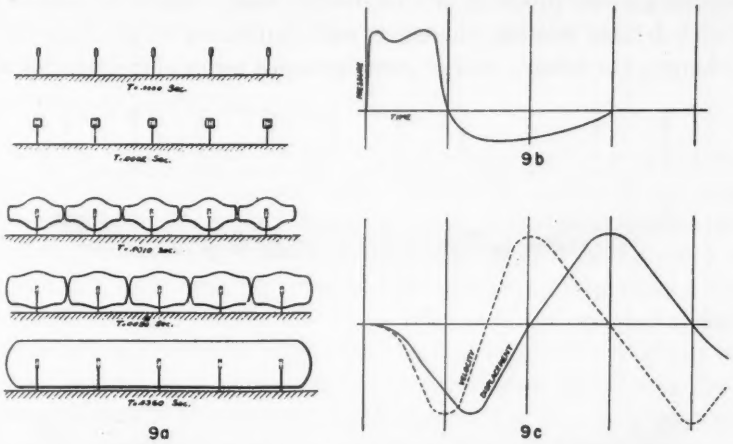

FIG. 9. The expanding shock waves merge into pressure envelope of the pattern area which is relieved by the outward motion of the gases, thus generating a positive pressure followed by a reduced pressure of longer duration, 9b. Charges were spaced 20 feet apart.

pattern area is set in motion outwardly which creates a reduction of pressure over the area.

Figure 9b shows a typical pressure-time curve as measured by a tourmaline crystal pressure pickup buried under the pattern area a few inches below the surface of the ground. From this curve it will be observed that the pressure builds up to a maximum as the direct shock waves from the individual charges strike the ground. Then, about the time this starts to drop off, the shock wave from the adjacent charge merges and builds the pressure up again. However, by this time the air surrounding the pattern area has been set in motion and the pressure drops, in some cases, to as little as one-fourth of an atmosphere. The reduced pressure will, in general, last about twice as long as the positive pressure and, from a comparison of Figs. 9b and 9c, it will be seen that such a sequence of forces should generate seismic energy having a rather narrow frequency range. As the earth starts to oscillate from rest, the length of time from the rest position to its first maximum displacement is one-fourth of a cycle, whereas the time required for it to move from its first maximum displacement to the maximum displacement in the opposite direction is one-half of a cycle time. Thus the duration of the negative pressure of twice that of the duration of the positive pressure

provides a means of controlling within limits the frequency of the seismic energy that is introduced into the ground beneath the pattern area. This is valid where the pattern spacing is less than that necessary to generate a frequency controlled by means of shock wave reflection.

By the proper variation of the size of the charges and the spacing between adjacent charges while maintaining other factors constant, it is possible to vary the frequency of the seismic energy over a rather wide range. This is achieved by means of the pressure pulse cycle produced by the merging of the shock wave and expanding gaseous products of a relatively closely-spaced pattern of charges. Starting with a large spacing, therefore, and continuing to decrease the spacing between charges, the seismic energy goes through a series of frequencies which are

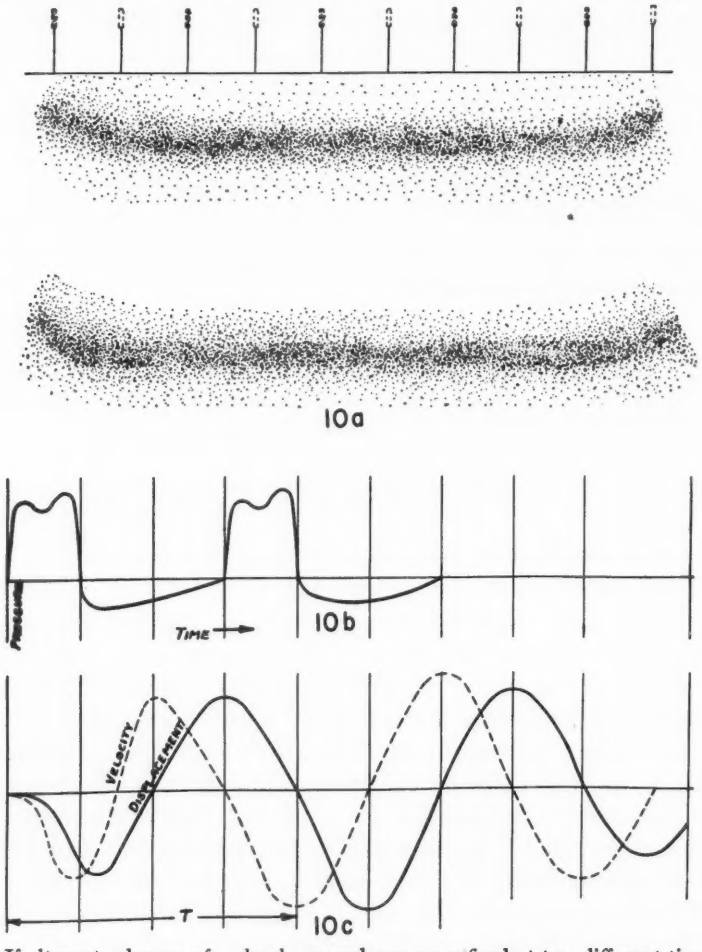

FIG. 10. If alternate charges of a closely spaced group are fired at two different times, a seismic pulse is produced whose frequency can be controlled within limits by controlling the firing time interval.

controlled by the timing of the two pressures imposed on the ground. The first is due to the direct shock wave under the charges, and the second is caused by the shock wave reflection between adjacent charges. If, however, the spacing is continually decreased, those two pressure impulses gradually merge together to form a single impulse followed by a reduced pressure.

The seismic pulses shown in Figure 7 for spacings of 17.5 and 35 feet have their frequency controlled by means of the pressure pulse technique rather than by shock wave reflections. It is therefore possible to obtain the same frequency from two entirely different pattern spacings as shown from the A and B groups of curves in Figure 8.

Sequence Firing Method of Frequency Control

It is possible to obtain two pressure pulses timed in the proper sequence by using sufficiently close spacings and firing half of the charges at the proper time interval in advance of firing the remaining charges. The frequency of the seismic energy will be controlled in a manner similar to the case of the shock wave reflection method. Controlling the frequency by sequence firing offers a wide range of possibilities. However for the maximum efficiency, the spacing of the charges fired in each group should be such that the frequency of the group itself corresponds to the frequency produced by the time delay introduced into the sequence firing. If this is the case, the frequency of the seismic energy generated is peaked in a narrower frequency range than is the case if the frequencies of the individual groups do not correspond to that used in the sequence firing.

In the case of a closely-spaced pattern of charges, the seismic wave fronts are essentially continuous over the pattern area as shown in Figure 10a, instead of being at isolated areas as is the case with the shock wave reflection technique. Figure 10b shows the fluctuation of pressure at the surface of the ground and Figure 10c shows corresponding velocity and displacement curves for the seismic transient produced. There are a great many different types of patterns that may be used with sequence firing. However, any sequence firing technique does impose a number of additional precautions that must be taken. First, the charges must not be placed close enough together so that they will be detonated by influence. In addition, care must be taken in connecting up the two groups of charges so that the wiring for the second group will not be damaged when the first group of charges is detonated. Three different types of pattern for sequence firing are shown in Figure 11. In all of these patterns the charges are placed close enough together so that a single positive pressure pulse is produced instead of the two as in the shock wave reflection technique. Figure 11a shows a double row of charges in which all the charges in one row are fired as one group and the charges in the other row as a second group. All the charges may be arranged in a single line in which alternate charges are fired as one group and the remaining charges as the second group. Patterns such as these produce a time-pressure cycle corresponding to that shown in Figure 10b.

Figures 11b and 11c are special cases in which an attempt is made to increase the duration of the second positive pressure to twice that of the first so that it corresponds to one-half cycle time instead of one-fourth cycle time as is the case with the first pressure pulse. This is accomplished by having the individual charges in the second group separated by twice the distance used in the first group. The time-pressure curves and velocity and displacement curves for patterns such as 11b and 11c are shown in Figures 11d and 11e. There age, of course, a great variety of combinations of effects that may be used, such as different types and spacings of patterns, either independently or in combination with sequence firing, to produce some sort of frequency control of the seismic energy that is introduced into the ground.

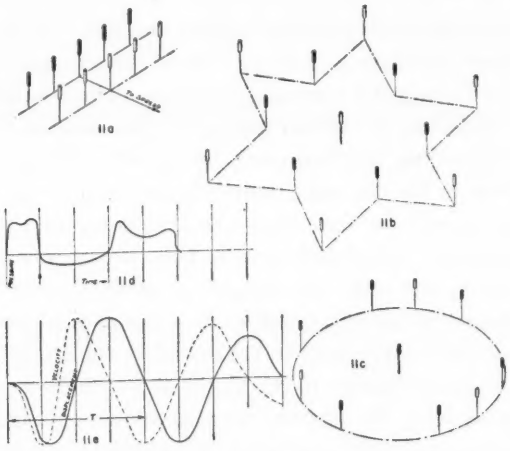

FIG. 11. Special sequence firing pattern. Close spacing of first charges fired indicated by dark charges in 11b and 11c, and larger spacing of remaining group generates a second pressure pulse of longer duration than the first, thereby improving the energy transfer.

In the sequence firing, as in the shock wave reflection technique, the ratio of the frequency of the air pressure at the surface to the seismic frequency is 1.33 for small patterns in the case of reflection shock wave, or two groups of charges over the same pattern area in the case of sequence firing. For very large patterns or sequence patterns over separate pattern areas, this ratio will decrease and approach unity as a limit. The reason for this is, of course, that if the two groups are sufficiently far apart, the surface of the ground under the second group will not have been set in motion from the first group of charges when the pressure is applied from the second group of charges. Figure 12 shows the relation between the time interval and the seismic frequency for both conditions and a third curve of low frequencies caused by the merging of the two events into a single pressure pulse. Also shown in Figure 12 are some experimentally determined frequencies, and tracings of the corresponding seismic pulses are shown in Figure 13.

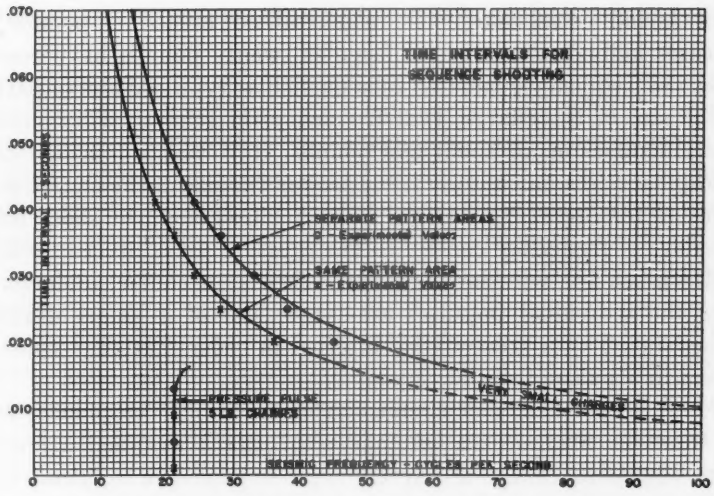

FIG. 12. Curves showing theoretical and points showing experimental values for seismic pulse by sequence firing over the same or over separate pattern areas and the lower frequency caused by firing the charges timed closely enough together to produce a single pressure pulse.

FACTORS USED IN CONTROLLING THE FREQUENCY AND THEIR EFFECT

Since the frequencies are determined by the magnitude, duration and sequence of application of the impulses upon the surface of the ground, the factors used in controlling these are the charge, the pattern, and the detonation procedure.

The Charge

Size.—The size of the charge plays a very important part in the determination of frequency by any of the techniques involved in determining that frequency.

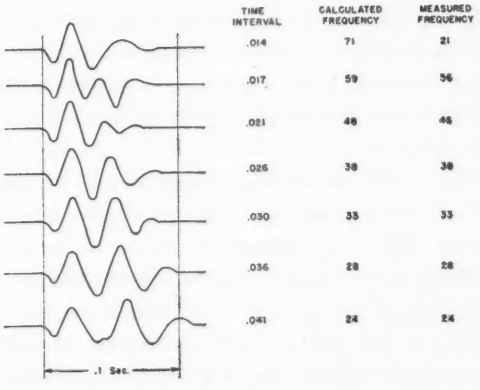

FIG. 13. Tracings of records of seismic pulse recorded by four-cycle geophones connected in series and buried deep under pattern area.

The size of the individual charge will, in general, not exceed ten pounds, although in a few cases individual charges as large as twenty pounds have been used. If one studies the frequency generated by a particular type and size of pattern while varying the size of the charge, that frequency, in general, will increase as the charge size increases up to about five pounds. However, it may not be affected or even drop back to a much lower frequency as the size of the charge is increased appreciably to ten or twenty pounds. The transition from the shock wave reflection procedure of frequency control to the pressure pulse procedure occurs at a larger pattern spacing with large charges. This is, of course, understandable in that since the individual impulses are larger and of a longer duration, they must be separated by a greater time interval in order that they constitute separate waves in a pulse of seismic energy.

Shape.—A great variety of charge shapes have been employed, ranging all the way from the Munroe shaped charge through a modified Munroe charge, flat charge, composite charge of different types of explosive to cylindrical charges of different length to diameter ratios. Although quite satisfactory results were obtained by the use of the modified Munroe shaped charge, it is not felt that they will receive extensive use because of the danger to personnel from the high velocity fragments and the accompanying fire hazard. Many satisfactory results have been obtained even in difficult areas by means of the flat charge, but in general, the frequency control is not quite as flexible by the use of the flat charge as it is in the case of the cylindrical charge conventionally available on the market.

Detonation Rate.—The question of the effect of detonation rate of the explosive upon the generation of useful seismic energy has been studied by several investigators. (Sharpe, 1942; Taylor, *et al.*, 1946.)

As a result of these investigations it is now generally accepted that for charges of equal energy in shot holes, the detonation rate of the explosive has little, if any, effect on the energy level of the resultant records. However, in the case of charges detonated in the air where the energy is being transferred to the ground by means of a shock wave, the situation is entirely different. The shock wave velocity as it leaves the surface of the explosive is equal to the detonation rate of the explosive; therefore, the higher the detonation rate the greater will be the energy in the shock wave.

Early tests on this were misleading because proper consideration was not given to the effect of detonation rate upon the frequency generated by the pattern. An elaborate and very extensive series of tests was undertaken to determine the real effect of detonation rate of the explosives. The results of these tests led to the definite conclusion that the seismic energy obtained from shots fired above the surface of the ground and having equal energy is very approximately proportional to the detonation rate of the explosives. Not only does a lower velocity explosive require the use of more explosive to obtain the same re-

sult, but this may even increase the cost and result in a louder noise for the same result.

Location of Cap.—Although the location of the cap is not very critical, essentially better results have been obtained, particularly with the shock wave reflection technique, the pressure pulse technique, and in most cases with the sequence firing technique, by placing the cap in the middle of the charge. Changing the cap to the bottom, or to the top produces a measurable decrease in the seismic energy produced, but this is so small that it probably would not be easily detected in actual reflection shooting, particularly if automatic volume control is being used.

Shielding.—The shielding effect of the expendable or indestructible support for the charge again introduces a very minor effect. An increase in this shielding effect tends to increase the frequency very slightly, in that it causes a very slight delay in the arrival time of the shock wave beneath the charge as compared to the arrival time of the reflection shock wave between charges, and hence an over-all decrease in this time internal.

The Pattern

Type.—There are, a great many different patterns that can be used in connection with the detonation of charges above the surface of the ground, however, the major ones have been previously discussed and it is only necessary here to comment upon the various effects produced by different types of patterns. The hexagonal 7- or 13-charge pattern is the one most extensively used, and in the case of the shock wave reflection technique the greater uniformity of spacing between charges, the narrower will be the range of seismic frequencies produced by the pattern. In the case of the pressure pulse technique, a straight line pattern will, in general, produce an appreciably higher frequency than will the two-dimensional pattern. This is explained by the fact that the expanding gases are free to escape off to either side of the line of charges, whereas in a hexagonal pattern, or any two-dimensional pattern, there is an interference from the adjacent charges. Therefore a somewhat longer duration of the positive portion of the pressure pulse is obtained.

Spacing.—The importance of the spacing between adjacent charges has previously been discussed and is, of course, the most important variable to be employed with the use of the method in the field. Charts similar to that shown in Figure 8 have been worked up for a great many different charge sizes and pattern spacings.

Height of Charge.—The height of the charge is a rather important factor from two standpoints. First, a variation in the height of the charge changes the arrival time of the energy directly under the charge with respect to the arrival time of the energy from the reflection of the shock wave between adjacent charges. For a given spacing, the higher the charge the shorter will be this time

interval and hence a higher frequency is produced. However, a more important factor has to do with a compromise between the desirable increase of area covered due to an increase in the height of the charge and the accompanying decrease in pressure per unit area on the ground. An important disadvantage of having the charge too low is the crushing effect on the ground and, consequently, the absorption of energy with the associated generation of high frequencies. It is also very important that the charges are not located too high above the surface of the ground. This causes a decrease in the velocity of the shock wave striking the ground, which plays an important part in the efficiency of the energy transfer at the surface of the ground. The expression $400(D_1V_1/D_2V_2)$ represents approximately the per cent of energy transferred to the ground, where D_1 is the density of the air, V_1 is the velocity in air, D_2 is the density of the surface of the ground and V_2 is the velocity of the seismic energy directly on the surface of the ground.

The air pressure at the surface of the ground under a pattern of 5 pound charges is approximately 100 psi, therefore the density has been increased about seven fold. Since the velocity of the shock wave as it reaches the ground under the charges is about twice normal sonic velocity, these two effects make a fourteen fold increase in this quantity. Another important factor is the effect of the height of the charges upon the radius of curvature of the wave fronts. Taking all of these various factors into account and including convenience of setting up the pattern, the height most commonly used is 8 feet.

Number of Charges.—In the case of the hexagonal triangularly-spaced pattern, the quantity of energy entering the ground is roughly proportional to the number of charges from three up to thirteen, or even nineteen, charges. There are, of course, many factors which enter into the selection of a pattern. The saving in time and caps may compensate for the slightly larger individual charges required for a 7-charge pattern as compared to a 13-charge pattern.

Detonation Procedure

The charges, in general, are detonated in one or two groups with the caps connected in series in each of the groups. The two groups are used only in case of the sequence firing procedure, but in most cases, it is necessary to use some sort of special blasting machine in order to ensure that all of the caps will be fired. If a good grade of seismograph cap is used and all the caps fired, it can be considered that the firing time of all of them is sufficiently simultaneous so that there will be no loss of energy due to a spread in firing time of the individual charges. The technique most commonly used for firing caps in series is some sort of a condenser-discharge type shooter. The condenser may be charged by means of batteries or a hand-cranked generator, or it may be connected directly across the generator in the conventional plunger-type blasting machine. It is, however, not satisfactory to connect the condenser across the terminals of the blasting machine, because this will hinder rather than aid in firing all charges simultaneously. In addition, the condenser may retain sufficient charge to fire the next

pattern when it is connected up. A number of sequence firing timers have been developed, including mechanical, electronic, and timing motor driven.

DISCUSSION

Areas in Which the Method Has Been Tested

Experimental tests have been made with the method in all of the major oil producing areas in North America and to a lesser extent elsewhere. In the mid-continent area, it has been tried on almost every type of surface condition. These include the sand and gravel areas of the Rio Grande Valley, the limestone surface of the Edwards Plateau, the caliche covered areas of New Mexico and the gypsum, anhydrites and sand-covered areas of western Oklahoma. After some experimentation in each of these areas the results obtained have been at least equivalent to those obtained by the conventional shot hole technique.

Figure 14 shows a few records obtained in widely distributed areas. The first two are shot hole and air charge records from the muskeg covered area near Edmonton, Alberta, Canada. The next two records were taken on Taku Glacier near Juneau, Alaska, with a snow cover over the glacier ice of more than thirty feet. The Tejon Ranch record was taken in the extreme southern end of the San Joaquin Valley where the gravel and boulder fill extends to a depth of 750 feet. Although this is considered a "no record" area by conventional shot hole technique, this record is typical of a line of five miles of continuous subsurface and was obtained with a total charge of only $6\frac{1}{4}$ pounds of explosive.

The Utah record was taken on a prospect where high drilling costs make seismic surveys by the conventional shot hole technique prohibitive. The last record was taken near Big Lake, Texas, on the edge of the Edwards Plateau.

Multiple Reflections

There has now been a sufficient accumulation of comparative records to demonstrate the almost complete absence of multiple reflections in the use of the Poulter method even in areas where they are very numerous when using the conventional shot hole technique. Although some interesting leads are being investigated, there is as yet no satisfactory explanation of this absence of multiple reflections.

The Use of a Pattern of Charges in Shallow Shot Holes

It has been proposed that the use of a pattern of charges in shallow shot holes would obtain the same result and would eliminate the air blast effect. There are certain areas in which it is possible by this procedure to obtain some reflections. However, the energy has all of the frequency characteristics of the conventional shot hole technique, is not subject to frequency control and is not directional. In difficult drilling areas it is also more difficult to use than a single shot hole and, in general, obtains a record that is inferior to a single shot hole record. At one time it was felt that the procedure might have some application

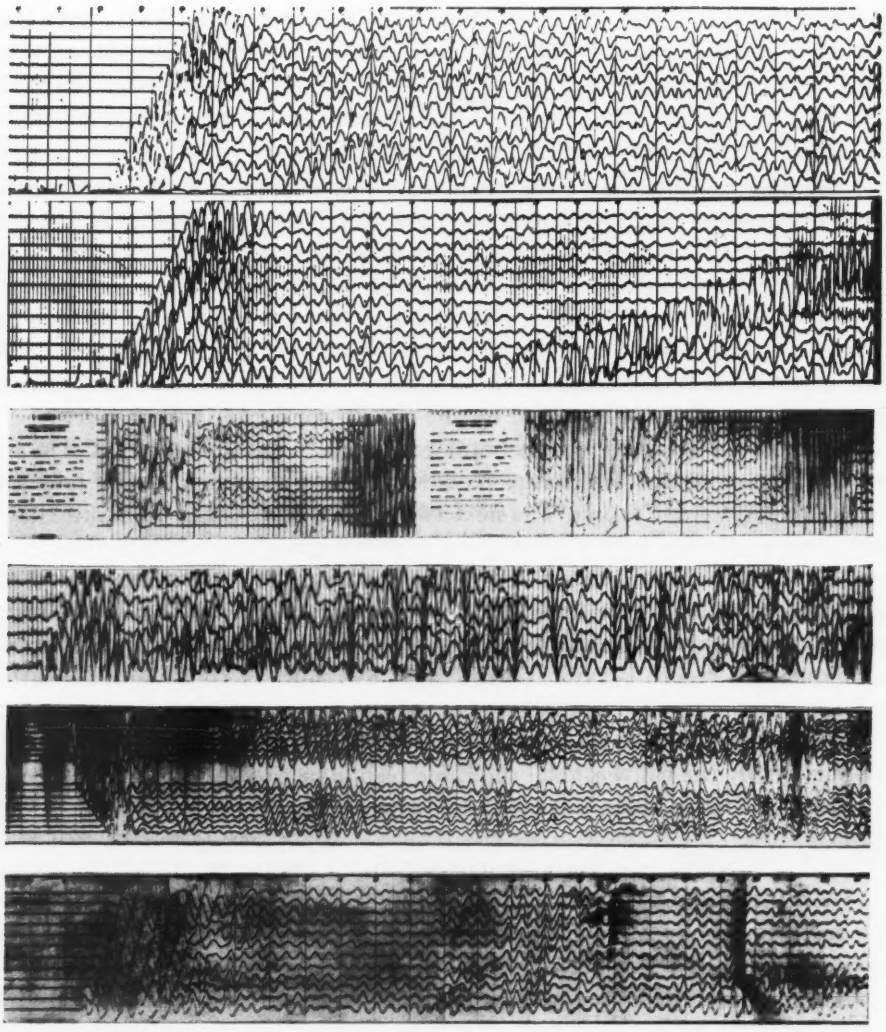

FIG. 14. Miscellaneous records.

Comparison records from Canadian muskeg. Upper record from shot hole, lower record from air charge. Two records of very early reflections from Taku Glacier. A record from Tejon Ranch, near Bakersfield, California. 750-foot boulder fill makes conventional method impractical. A typical record from a Utah prospect. A record from near Big Lake, Texas, on the edge of the Edwards Plateau.

in connection with air shooting where a shot point came close to buildings. However with the reduction in the charge size associated with the more accurate frequency control, even this possibility seems to be disappearing.

Weathering Corrections

The directional characteristics of the seismic wave causes a lower level of energy early on the record, as compared to records from shot holes. In some

areas, the earliest arrivals are not perceptible on all traces. This fact, combined with the fact that the basic principles obviate the availability of any figure corresponding to the commonly-used up-hole time, has caused some question as to the calculation of weathering corrections.

One interesting weathering method which has been used with considerable success is to correct all times down to a deeper horizon than the commonly used "base of weathering." The early secondary refractions are frequently very pronounced and readable on these records, as illustrated in Figure 3c. All corrections can then be made to that refracting horizon. It is either assumed to be flat or any knowledge of its profile is applied. This method has a distinct advantage in comparison with others in that the "base of the weathering" is often very indefinite and we have no definite assurance that the conventional shot-hole effectively penetrates all of the weathered layer.

Where first arrivals or early refractions picked from the reflection records do not give satisfactory weathering information, it may be desirable to resort to separate weathering shots. These may be either small charges buried a few feet, or single air charges, off the ends of the spread.

Tests are currently being conducted on the accuracy and usefulness of several different methods of weathering corrections, including those assuming curved-path travel of the shallow refractions. These tests also include an evaluation of the common errors of "up-hole time" measurements and corrections, for purposes of comparison.

Quantity of Explosive Required

The quantity of explosive required for use with this method as compared with the conventional shot hole technique is a question on which there are data to support almost any ratio. In the early production use of air shooting in West Texas in 1947 and 1948, charges of as much as 260 pounds were being used on prospects where shot hole charges as small as 50 pounds in 150 to 250 foot shot holes gave equivalent energies. With the continued development of frequency control the quantity of explosive required has been rapidly decreasing.

During 1948 it is estimated that an average of about three times as much explosive was used per shot as was required in the same area in shot holes. In 1949 that quantity has been reduced by about 50 per cent and the present trend is rapidly in the direction of a reduction in quantity of explosive and an improvement in quality of records.

In July of 1948 some experimental tests were made with this method for comparison with the conventional shot hole technique in an area which was recognized as a "no record" area. For these tests a line of stations was shot along the southern edge of Sections 27, 28 and 29 in Block 11 in Reagan County, Texas. Neither method produced records containing usable reflections. Sections of typical records from a station of that line selected because of its ready accessibility for later comparison purposes, together with a recent record covering the same subsurface section, are shown in Figure 15. Record A was taken with a 150-

pound charge at a depth of 185 to 210 feet. Record B was taken with a 19-charge air pattern totalling 86 pounds.

These tests were made, however, before the techniques of controlling the frequency had been developed and the pattern that was selected was one which it has since been determined peaked the frequency primarily in a very much higher frequency range than was suited to the area. In both cases in the July

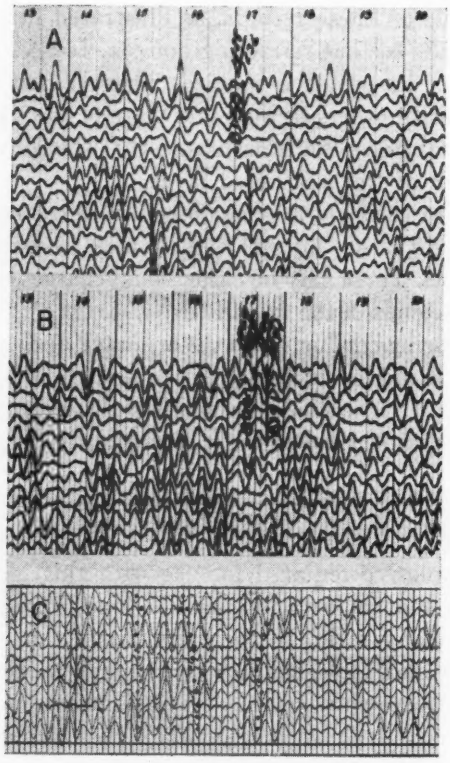

FIG. 15.

A.—Mixed record taken with 150 pounds of explosive in 185 to 210 foot shot hole (NR).

B.—Mixed record taken with 19-charge pattern using 86 pounds of explosive, without frequency control (NR).

C.—Unmixed record using less than 5 pounds total charge, but with frequency control.

Spacing of groups of four geophones per trace was 110 feet in A and B, and of single geophone per trace was 135 feet for C.

1948 test the spacing between the groups of geophones was 110 feet and mixing was used between adjacent traces.

Following the development of more accurate methods of frequency control and based upon more experience in the use of this method, Record C was obtained using a total charge of less than 5 pounds of explosive.

However, the most important factor is not that the explosive has been reduced from one hundred or more pounds to less than 5 pounds nor even the saving in time required to set up the more effective pattern. It is the fact that a reflection is obtained, without mixing, using a single geophone per trace with a greater spacing between geophones and in an area previously considered a "no record" area.

ACKNOWLEDGMENTS

On behalf of the sponsor of this development, the Institute of Inventive Research, the author wishes to thank R. P. Green and other members of the staff of the Republic Exploration Company and Engineering Industries for their early guidance and continued assistance in the development of instrumentation and practical field procedures; G. O. Rockwell, Humble Oil & Refining Co., for his valuable assistance in making many of the fundamental studies without which the method could not have developed so rapidly; N. G. Johnson and the du Pont Company for their assistance in matters pertaining to explosives, caps, and safety procedures; the Technical Instrument Company for special instrumentation; Dr. Joseph A. Sharpe for valuable criticism and suggestions; and the many companies and field crews without whose patience and cooperation through extensive field tests there would have been no method about which to prepare an article.

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THE PROGRESSIVE DETONATION OF MULTIPLE CHARGES IN A SINGLE SEISMIC SHOT*

LORENZ SHOCK†

ABSTRACT

The relative efficiencies of various sizes of explosive charges for the generation of seismic energy were investigated and a procedure devised whereby a number of charges of the most efficient size would be detonated progressively in such a manner that the energy from all the individual charges would arrive simultaneously at the recording position. The results of investigations of this system of progressive detonations, using both horizontal and vertical spacings of the individual charges, are presented and its possible application in reflection and refraction seismic surveys is discussed.

This paper is in the form of a progress report on certain experimental work that is being conducted in West Texas. Due to the fact that the work is still in progress, in some instances, the investigations are incomplete and we are unable to draw final conclusions. However, all of the data to be presented have been checked by at least two separate and independent observations and it is considered that they are reliable, and that further work will tend only to provide more detail without materially altering the present findings.

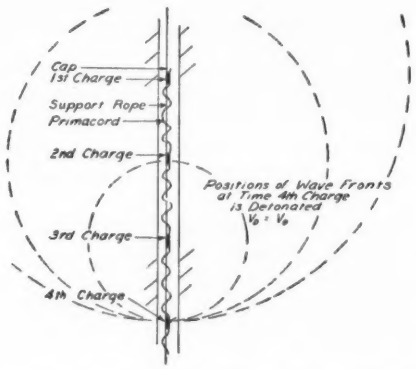

FIG. 1. Arrangement of charges for progressive detonation in reflection shooting. Rate of detonation is controlled by length of primacord between charges. Wave fronts illustrate additions of energies along vertical path when detonation rate is equal to the seismic velocity.

In the past a number of systems have been suggested for replacing the single large charge, usually used in seismic prospecting, with a number of relatively small charges, in the hope that this would provide a more efficient method of initiating seismic energy and at the same time reduce the random undesirable

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energies originating at the shot point. It was with these same purposes in mind that the present system involving the progressive detonations of multiple charges was proposed. The system proposed for reflection recording is illustrated by Figure 1 and that for refraction recording by Figure 2. In both cases we have a series of small charges interconnected by primacord. For reflection recording the series is arranged in a vertical position in a shot hole by means of a support rope. For refraction recording the series is distributed in a horizontal position along the surface. By varying the amount of primacord between adjacent charges the time interval between the detonations of the successive charges can be regulated and thus the effective rate of detonation for the entire series can be controlled. If a vertical series, as illustrated in Figure 1, be detonated at the top and if the rate of detonation be selected to be equal to the rate at which seismic energy progresses through the surrounding medium, the energy from all the charges will be "in phase" along a downward path and "out of phase" along all other paths. This effect is illustrated by the positions of the wave fronts from the

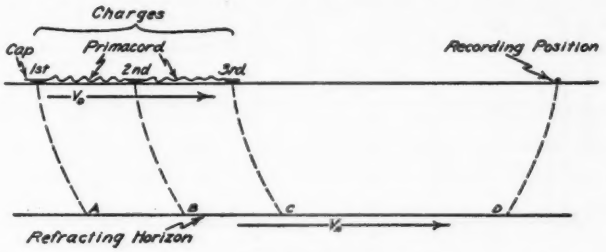

FIG. 2. Arrangement of charges for progressive detonation in refraction shooting. Rate of detonation is controlled by length of priamcord between charges. Energies from separate charges are "in phase" when detonation rate is equal to the horizontal velocity of the refracting horizon.

first three charges at the time the fourth charge is detonated. It was hoped that this arrangement would provide effective vertical discrimination of the energy and reduce the undesirable energies originating at the shot point.

Essentially the same results may be achieved for refraction recording using the horizontal spacing as illustrated in Figure 2. Since the paths from the surface to the refracting horizon are equal from all the charges, and the distance between the points of incidence on the refracting horizon is equal to the distance between the charges, the energy waves from all the separate charges will be "in phase" at the recording position if the rate of detonation of the charges is made equal to the horizontal velocity in the refracting horizon. For example, the time for the energy from the first charge to progress from the "Surface" to *A* and then on to *B* would be exactly equal to the time for the detonation wave to progress from the "First" to the "Second" charge plus the time for the energy wave from the "Second" charge to progress to the point *B*.

In both of the examples presented the use of primacord was proposed as the means of controlling the detonations, but other methods may be used. For the

vertical arrangements, however, (Fig. 1) it should be borne in mind that the upper charges will be detonated first and would cut any control leads extending from a deeper charge to the surface. The possible use of short period delay blasting caps as used in quarry blasting was investigated but it was found that the delay periods were too long and too inaccurate for these purposes. In the case of the horizontal arrangement for refraction shooting all the charges are accessible to the surface and each may be primed and the detonation rate controlled electric cally, if desired.

After favorable results were obtained in several preliminary trials of the proposed systems a series of experiments were undertaken to investigate the several variable factors involved in making up such a series charge. The factors investigated were, charge sizes, charge spacing, and detonation rates, as well as

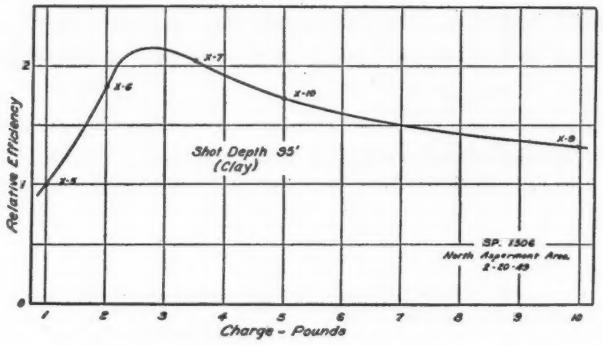

FIG. 3. Efficiency curve for charges detonated at 95 feet in clay. Relative efficiency equals Relative Energy/Size of Charge. Energy of one-pound charge taken as unity.

the effects of multiple charges. For comparative purposes the trace deflections for a given event on the recordings were measured and it was assumed that the seismic energy varied directly as the square of these deflections. In making a series of comparative shots all instrumental factors were held constant and the automatic gain control was eliminated from the amplifiers. If, during any series, it became necessary to alter any factor other than the one under investigation at least one shot was repeated to provide a "tie" between the two sets of data. Also, whenever possible, certain reference shots were repeated in a series to check upon the possible effects of "hole fatigue" or other factors introducing changes which would be misinterpreted.

One of the first factors to be investigated was the relative efficiencies of various sizes of charges for the initiating of seismic energy. The tests revealed that the efficiency of a given charge is a function of both the size of the charge and the material in which it is detonated. For the purpose of making comparisons, the relative efficiency of a given charge was defined as the relative energy of the charge divided by the weight of the charge, and these values were computed and

plotted as functions of the charge size for each series of tests. These results are presented in the following figures.

Figures 3 and 4 present typical efficiency curves for charges detonated in clay or shale. The curve of Figure 3 is for relatively large charges in a deep hole and

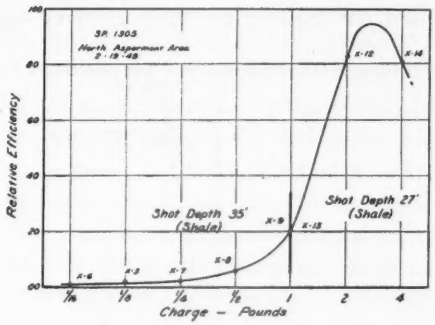

FIG. 4. Efficiency curve for charges detonated at 27 and 35 feet in shale. Relative efficiency equals Relative Energy/Size of Charge. Energy of 1/16-pound charge taken as unity.

Figure 4 for small charges in a shallow hole. On both curves it is noted that as the charge is increased the efficiency increases until it reaches a maximum at about three pounds and then decreases and continues to decrease for all larger charges. In all the cases investigated the existence of a charge of maximum

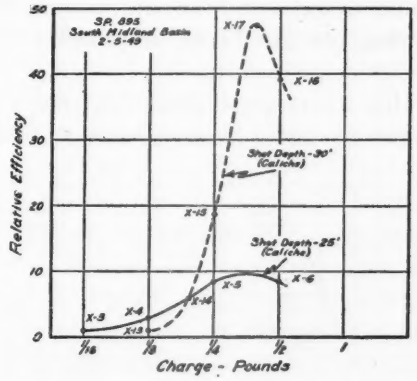

FIG. 5. Efficiency curve for charges detonated at 25 and 30 feet in caliche. Relative efficiency equal Relative Energy/Size of Charge. For the 25 foot depth the energy of a 1/16-pound charge is taken as unity and for the 30 foot depth the energy of 1/8-pound charge is taken as unity.

efficiency was definitely established. It appears also that the most efficient charge is relatively large for detonations in pure clays and shales, becomes smaller for more calcareous shales, and is quite small for limestone or caliche. This is illustrated by Figure 5 which presents the results obtained for two series of shots

placed in caliche. Both of these curves show maximum efficiencies at about 1/8 pound.

The data for Figures 3 and 4 were derived from the average values determined from all the good reflected events on the records. However, as reflected events could not be obtained with small charges in the caliche the method illustrated by Figure 6 was devised for measuring their relative energies. A water seis-

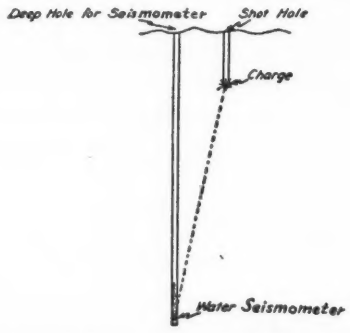

FIG. 6. Method for measuring relative energies directed downward from small charges. The energies are assumed to be proportional to the squares of the "first break" amplitudes recorded by the water seismometer.

mometer with the same response characteristics as the regular seismometers was placed in a deep hole and the charges detonated in a near-by shallow hole. The relative energies directed downward from the various charges could then be determined by comparing the first-break amplitudes recorded by the water seismometer.

After determining that a charge of about 1/4-pound was most efficient for shooting in a caliche hole, a series of shots were taken in a hole of this type and

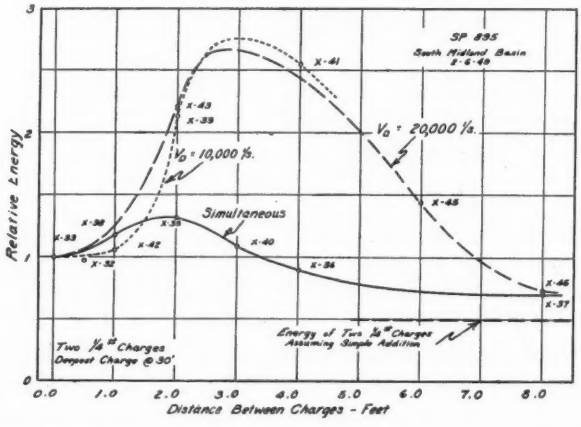

FIG. 7. Illustrating the effect of varying the spacing between two 1/4-pound charges for three rates of detonations. The energy of a single 1/2-pound charge is taken as unity.

the effects of varying the spacing between the two charges and the rate of detonating them were observed.

Figure 7 presents the results obtained from these tests. The curves are plotted to show the change in the energy resulting from a change in the spacing between the two charges. The solid curve shows the results when the two charges are detonated simultaneously; the dashed curve is for a detonation rate of 20,000 feet per second; and the dotted curve for a rate of 10,000 feet per second. These curves are all referred to unity for the energy of a single 1/2-pound charge which is equivalent to zero spacing between the two 1/4-pound charges. It is obvious that there is insufficient data to adequately define the upper two curves in the neighborhoods of their maxima, but a number of observations may be made:

First, and most significant, is the fact that the existence of maxima is established definitely for all the curves, and that these maxima are at points somewhat removed from the origin. For the simultaneous detonations the maximum occurs at a spacing of about 2 feet. For the progressively detonated charges they occur at about 3 feet.

Second. For the upper two curves the maxima exhibit relative energy values of about three times that of a single 1/2-pound charge and about ten times that of a single 1/4-pound charge.

Third. The relative heights of the maxima exhibited by these curves suggest that the greatest energy is derived from the spaced charges when they are detonated at a rate of 10,000 feet per second, which is approximately the seismic velocity of the surrounding medium.

Fourth. Once the maximum is attained an extension of the spacings thereafter results in such a decline in the energy that the spacing itself is ineffective and the energies derived from the spaced charges become less than that from a single charge of the same total amount of explosive.

Fifth. The facts that the curves exhibit these maxima and that the energies derived from the two charges are so much greater than can be explained by the simple addition of energies from the two separate charges must be interpreted to mean that there is some interaction between the charges which promotes a greater efficiency of energy transfer for the spaced charges.

It would be desirable to develop the curves for lower detonation velocities but there are practical limitations to the amount of primacord which can be introduced between the charges. Other means of controlling the detonations for low velocities are under consideration.

To further pursue these experiments with spaced charges, shots were made in a number of holes, far removed from each other, in which the energies from spaced charges detonated progressively were compared with the energies from single charges. In all cases it was found that more energy was derived from the spaced charges than from the single charges if the detonation rate was approximately equal to the seismic velocity in the medium surrounding the charges. The results of two of these tests are shown in Figures 8 and 9.

Figure 8 reproduces the equivalent portions of several reflection recordings

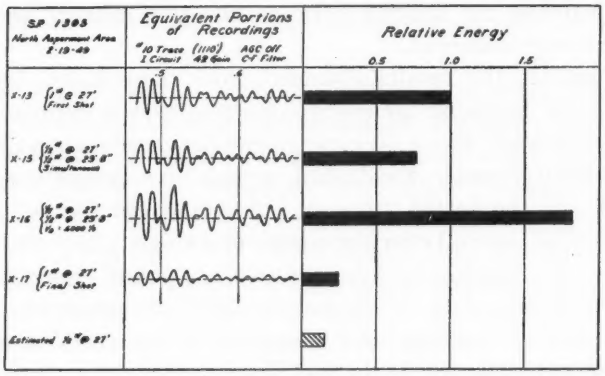

FIG. 8. Reproductions of the equivalent portions of four seismograms to illustrate the effects of multiple charges on reflected energies. Relative energies computed from the trace amplitudes of all the events recorded are shown graphically. Energy of a single one-pound charge is taken as unity.

taken to show the energies from two 1/2-pound charges spaced 32 inches apart as compared to that of a single 1-pound charge. The upper trace is for a single 1-pound charge; the second trace is for two 1/2-pound charges detonated simultaneously; the third trace for two 1/2-pound charges detonated progressively with a velocity of 5,000 feet per second, which is equal to the seismic velocity at this point; and the lower trace is for another single 1-pound charge taken after the other shots to check the possible effect of "hole fatigue." This illustrates that it is possible to nearly double the energy from the given amount of explosive by dividing into two separate charges. The effect of "hole fatigue" is seen to be quite large but this would tend to give the first single 1-pound charge the advantage over the other latter charges from an energy standpoint.

Figure 9 presents the same type of data as Figure 8 taken from another point

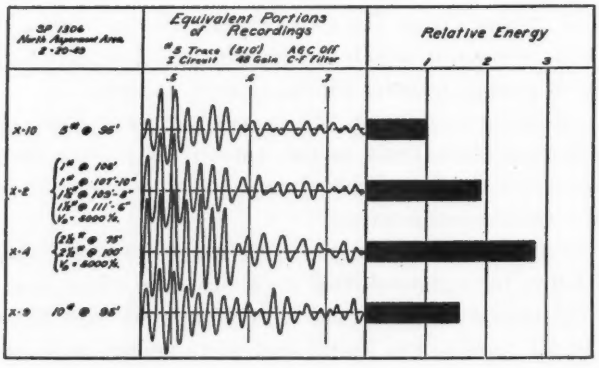

FIG. 9. Reproductions of the equivalent portions of four seismograms to illustrate the effects of multiple charges on reflected energies. Relative energies computed from the trace amplitudes of all the events recorded are shown graphically. Energy of a single five-pound charge is taken as unity.

and involving much larger charges. In this case the first trace is for a single 5-pound charge, the second trace for four small charges 22 inches apart and totaling 5 pounds, the third trace is for two 2.5-pound charges 25 feet apart, and the fourth trace for a single 10-pound charge. For both cases the detonation velocity for the multiple charges was equal to the seismic velocity in the surrounding material. In this case, as before, a relatively large amount of energy is indicated for the progressive charges; in fact, nearly twice as much energy is derived from two 2.5-pound charges as from a single 10-pound charge.

In recording data of the type used in preparing Figures 8 and 9 it was necessary to eliminate the Automatic Gain Control from the amplifiers in order that the trace deflections would be the proper functions of the seismic energy. With such an uncontrolled system only a few traces could be recorded for each shot and only a limited portion of each recorded trace was of a usable amplitude. In

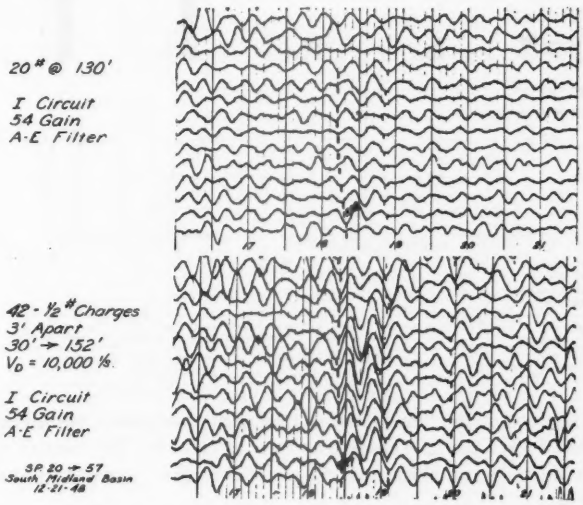

FIG. 10. Reproductions of the equivalent portions of two production type seismograms to illustrate the effect of multiple charges in reflection recording.

Figure 10 is reproduced the equivalent portions of two reflection profiles recorded in the normal production manner. These recordings were made in a relatively insensitive area with a large amount of caliche present in the shot hole. The upper recording is from a single 20-pound charge tamped with 30 feet of water and placed in what would be considered to be a good sensitive spot in the shot hole. The lower recording is from 21 pounds made up from 42 separate 1/2-pound charges spaced three feet apart and detonated at the rate of 10,000 feet per second, the approximate velocity of the surrounding material. This series of charges extended 122 feet up the shot hole and only the lower 30 feet was tamped with water. The relative energies and qualities of the two recordings are obvious.

In addition it should be said that it was necessary to use a single charge of 80 pounds to produce a record equivalent to the 21-pound progressive charge.

To investigate the possible application of the horizontal arrangement of charges for refraction shooting, several series of recordings have been made using short off-set refractions of the type usually used for determining weathering depths. In computing the relative energies for these shots the amplitudes of the first-break deflections were measured and the seismic energy assumed to vary directly as the square of these amplitudes.

Figure 11 presents reproductions of the recordings for four such shots. The upper traces are for a seismometer off-set 400 feet from the shot point and the lower traces for a seismometer offset 800 feet. Reading from left to right, the

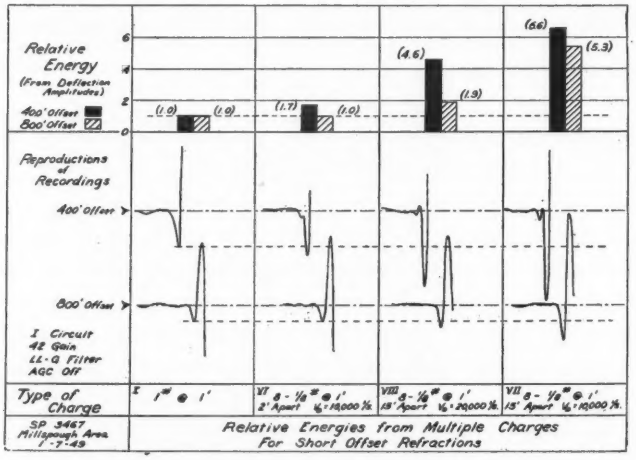

FIG. 11. Reproductions of the "first breaks" from four short offset weathering type refraction shots to illustrate the effect of multiple charges on trace amplitudes. The relative energy represented by each deflection is illustrated graphically at the top of the figure. The energy of a single one-pound charge is taken as unity.

first recording is from a single 1-pound charge; the second, from 8 separate 1/8-pound charges spaced 2 feet apart; the third, from eight, 1/8-pound charges spaced 15 feet apart; and the fourth, from eight, 1/8-pound charges spaced 15 feet apart. The detonation velocity for the second and fourth series was 10,000 feet per second; and for the third series it was 20,000 feet per second. All the charges were buried at a depth of about one foot.

The relative energies of the various series are presented graphically at the top of the figure. Here, again, we observe the same type of energy increase for the multiple charges detonated progressively as was observed for the reflection shots, using the vertical arrangement of the charges. In the case of these shots the energy appears to increase with the spacing between charges and with a decrease in detonation velocity. The velocity of 10,000 feet per second is approximately

equal to the velocity in the refracting horizon, and the effects of velocities below that figure were not investigated.

At another point, and using a similar system, a series of shots were taken to determine the effect of the number of individual charges on the total energy. The results of this investigation are presented in Figure 12 and illustrate that the total energy increases as the number of individual charges is increased. The curve rises rather abruptly as the number of charges is increased from 1 to 4 and from 4 to 8, but tends to level off as the number is increased from 8 to 16. It should be noted that the scale for the number of charges in the series is not linear. In making this test the total spread of the charges, i.e., the total distance from the first to the last charge in each series, was held constant, except for the

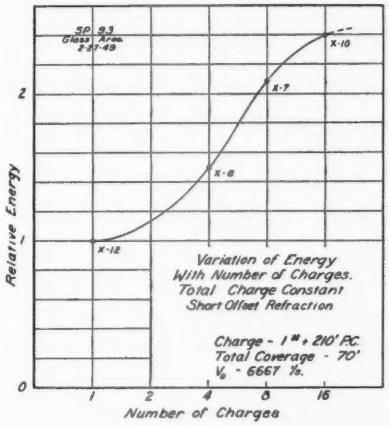

FIG. 12. Illustrating the effect of the number of individual charges on the total energy from a given amount of explosive. The energy of a single one-pound charge and 210 feet of primacord is taken as unity.

single charge. Also the velocity of detonation and the total amount of primacord used were held constant. For the single charge the primacord was spread out over the same distance as for the other charges and connected to detonate after the charge. This was done to eliminate the possibility that the added energy observed resulted from the primacord.

In summarizing the results of these experiments, we feel that we have been able to demonstrate that a series of small charges detonated progressively are much more efficient for initiating seismic energy than a single large charge. These experiments are still in progress and future investigations will consist of more work along these same lines together with the development of techniques for applying these results on a production basis, for both reflection and refraction surveys.

At the present time it appears that the principal benefits to be derived evolve from the fact that the total amount of explosive used may be reduced. This

would result in a substantial saving where large charges are used, would aid in helping to reduce the loss of shot holes, and should increase the record quality by reducing the undesirable energies generated by large charges.

Work will be conducted to determine the possibility of using one or more shallow holes at each shot point rather than a single deep hole. At the present writing the method appears to hold some promise along these lines, but the results are inconclusive.

In closing, the writer wishes to express his appreciation to the officers and management of the National Geophysical Company for their provision of the equipment and materials used for the experimental work, and their suggestions as the work progressed. He also wishes to express particular thanks to the several party chiefs and party personnel for their whole-hearted cooperation in conducting these experiments.

REFLECTED ENERGY VARIATIONS RESULTING FROM SMALL CHANGES IN SHOT HOLE AND SPREAD LOCATIONS*

CARL H. SAVIT†

ABSTRACT

Examples of seismograms and cross sections are presented to illustrate changes of considerable importance resulting from relatively minor displacements of shot holes and spreads. Records are exhibited from continuous profiling lines which were shot from separate lines of shot holes on opposite sides of a single line of spreads, as well as from lines which were shot from a single line of holes but which were recorded simultaneously on separate parallel spreads. A comparison of the results of conventional spread arrangements and of the parallel line or "H" spread technique as used in difficult areas is made.

INTRODUCTION

Seismic exploration in some areas has reached a point at which the currently used seismic reflection technique is inadequate to produce definitive results. It was with the intention of developing a practicable method of exploring such marginal areas by means of the reflection seismograph, that the techniques described in this paper were devised. It was in 1942 that these methods were first put into effect, under the supervision of Dean Walling, by Dupree McGrady, who was then a Western Party Chief. The areas considered to be suited to these experiments consisted of regions which had been explored from time to time by conventional methods with indecisive or inadequate results. That these methods could be given a thorough trial is largely due to the progressive and most generous support and encouragement of the Tide Water Associated, Seaboard, and Union Oil Companies in the Raisin City Area and of the Richfield Oil Corporation in the Cuyama Valley.

EXPERIMENTAL TECHNIQUE

The basic principle common to all the spread-shot hole relationships to be discussed in the present paper is that of obtaining pairs of relatively closely spaced, parallel profiles and of treating the results from these pairs as a unit in computing and plotting. While it might be expected that a minor parallel displacement of a spread should leave the quality and quantity of reflections essentially unchanged, it is the purpose of this paper to demonstrate important differences which result from parallel displacements of the order of only a few hundred feet or less.

The two elementary ways of achieving a parallel displacement of spreads, together with a few of the variants which have been employed from time to time, are shown in Figure 1. The method most economical in both time and money is

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† Western Geophysical Company, Los Angeles, California.

that of the "H" spread in which there are two parallel seismometer spreads with one shot hole serving for both spreads. The two profiles are, of course, recorded simultaneously, resulting in the obtaining of two parallel profiles with but one dynamite charge and one drilled hole.

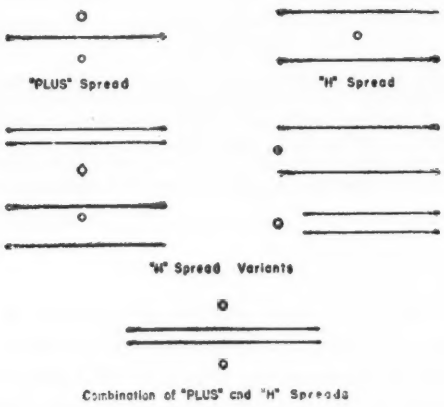

FIG. 1. Spread arrangements.

Early in the program, prior to the availability of the special cables and reels needed for the "H" spread, dual profiles were obtained using two shot holes and one seismometer spread. This arrangement will, for convenience, be referred to as the "plus" spread. In most of the recent work "plus" spreads have been replaced almost entirely by "H" spreads which have, indeed, been adopted as standard technique in certain areas.

RESULTS

Although conventional recording and shooting procedure in the Raisin City Area had produced usable data, the records were generally poor and the reflection continuity was usually quite erratic. The resultant gaps in the cross sections required considerable correlation across one, two, three, or more stations. Only occasionally were the finer details of the structure definitely detectable, a serious failing in this area of low relief. In an effort to obtain sufficient reflections to be able to carry reflection continuity across the entire prospect, the bulk of the Raisin City Area was covered with continuous "plus" spreads, the shot holes being respectively 300 feet offset from the spreads on opposite sides.

Figure 2 is substantially a direct reproduction of the original cross section obtained in the field on the TSU-H Line which extends from the south-westerly corner of Section 14, T15S, R17E due northeast a distance of twelve-thousand feet, cutting across the northwesterly flank of the Raisin City field. (Sloat, 1949).

Figure 3 shows the same section as it would have appeared had it been shot in the conventional manner from the southeast offset throughout. It is to be noted

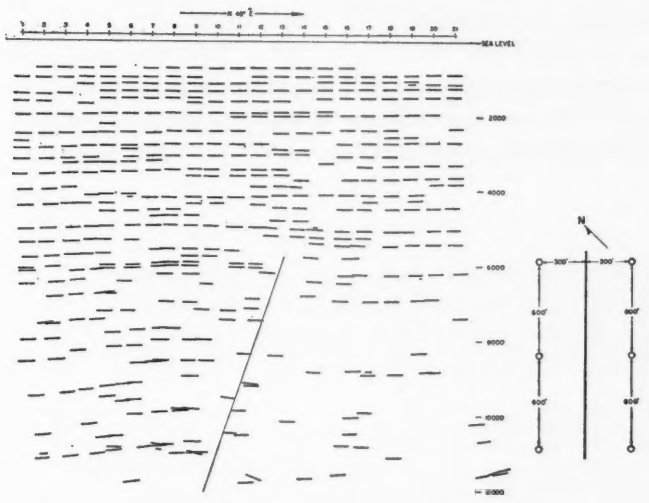

FIG. 2. TSU-H line, Raisin City, California, "plus" spreads, composite section.

that reflection continuity is appreciably impaired. In this particular case, such a failing may well have led to an improper interpretation of the section since the anticlinal structure under positions 7 to 10 at just above 6,000 feet is largely lost as is the lensing of beds under positions 12 to 17 between 4 and 5 thousand feet.

Figure 4 again shows the same section as it would have appeared if it had been shot from the northwest offset and again we see the impaired continuity and loss of detail especially in the very shallow and very deep parts of the section.

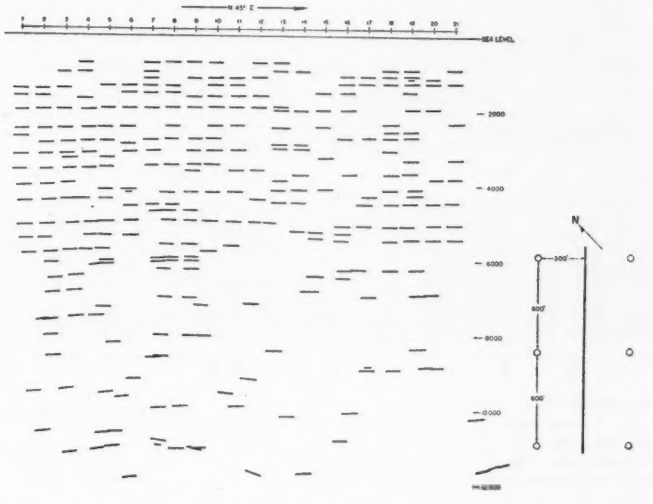

FIG. 3. TSU-H line, Raisin City, California, "plus" spreads, South-easterly offset only.

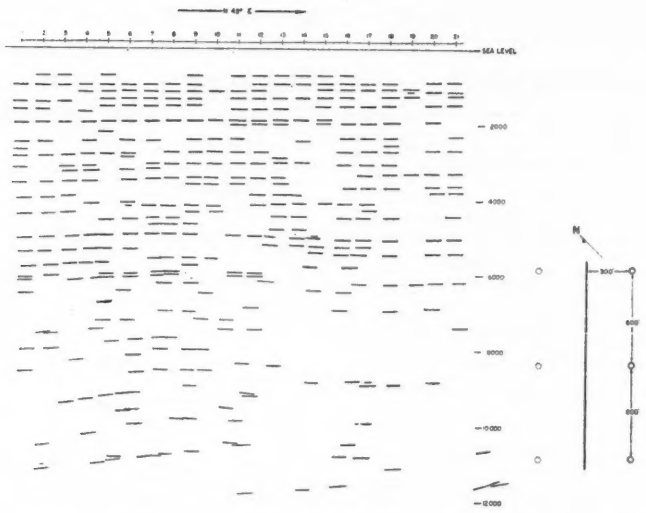

FIG. 4. TSU-H line, Raisin City, California, "plus" spreads, north-westerly offset only.

Figure 5 and Figure 6 show two pairs of records from "plus" spreads on the TSU–H line which illustrate the manner in which reception differs from shot holes on opposite sides of a line. Arrows indicate cases in which there is an outstanding difference in reflection quality between the two sides. Care has in all cases been taken to avoid instrumental or other extraneous variability. Both pairs are chosen so that charges, charge depths, and instrumentation are substantially

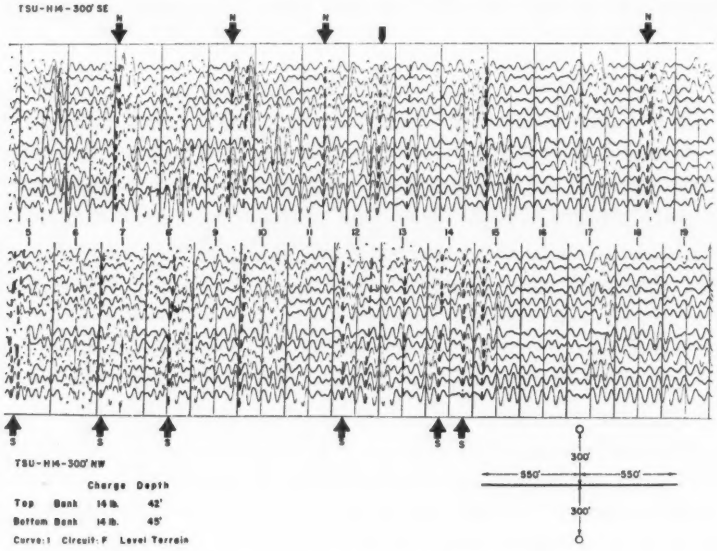

FIG. 5. "Plus" spread, Raisin City Field, California.

the same for both records of each pair. The seismometers and cables are not moved in going from one side to the other with the shooting, avoiding any variability due to changes in weathering. It is especially noteworthy that neither side can be classified as generally "good" while the other side is "poor." Reflections appear from one side or the other more or less indiscriminately on the two records.

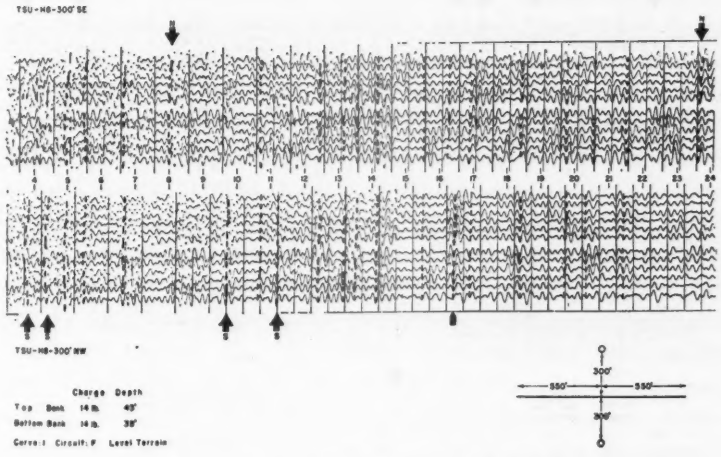

FIG. 6. "Plus" spread, Raisin City Field, California.

Later work in the Raisin City Area near Kerman employed "H" spreads with the same general quality of results. Differences between reflections obtained from the two legs of the "H" were similar in nature to those obtained from the two sides of the "plus." In the case of the "H" spreads, however, since the two legs are recorded simultaneously, variations of charge, shot hole, caps, tamping, and so on, are completely ruled out as interfering factors. Figure 7 illustrates a typical

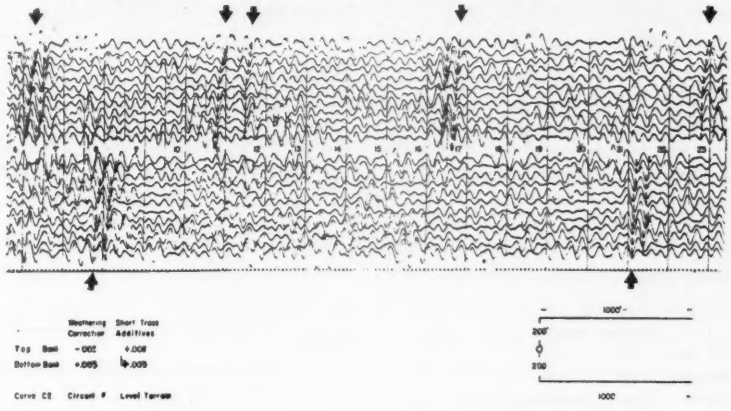

FIG. 7. "H" spread, vicinity of Kerman California.

record obtained on an "H" spread in the same general area covered by the "plus" spreads.

In an effort to ascertain the extent of the influence of distance, a number of "H" spread records were taken with the legs of the "H" only *ten feet apart*, the shot hole being offset on the same side of both spreads. The totally unexpected

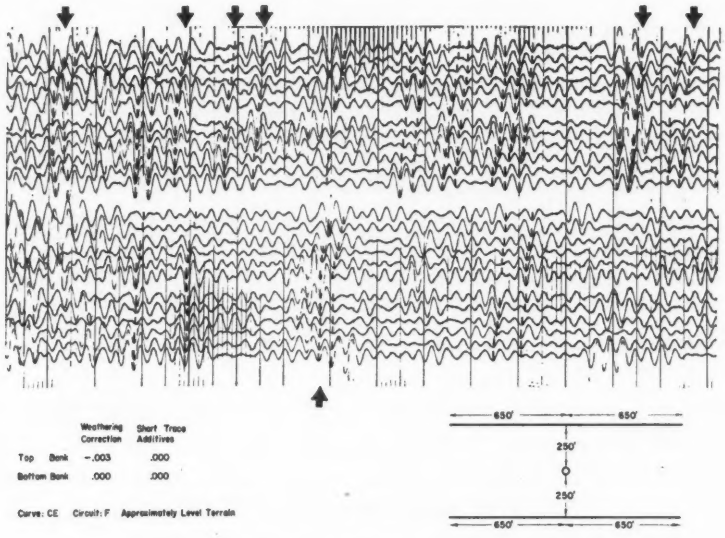

FIG. 8. "H" spread, Cuyama Valley, California.

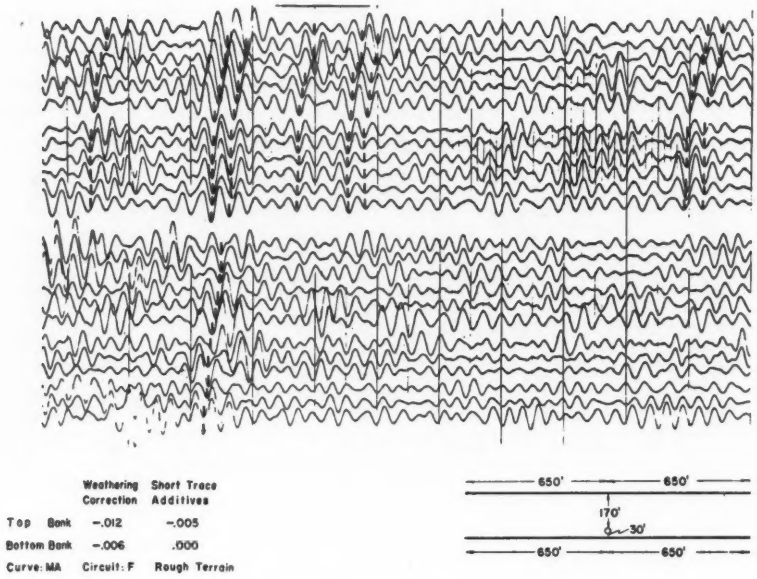

FIG. 9. "H" spread, Cuyama Valley, California.

result of this experiment was that there was still variation between the records of the two spreads, although of not as severe a nature as was the case when the spreads were six hundred feet apart.

As a further illustration of the results of using the "H" technique, portions of two records from the Cuyama Valley are presented. The situation in that area is quite different from that in the Raisin City Area. Conventional techniques produced very little useful information. Prior to 1948, seismic exploration in the Cuyama had consisted solely of an occasional reconnaisance line being shot, followed by an immediate abandonment of the prospect due to, among other reasons, the relatively poor quality of the seismic data. The problem was mainly that of obtaining enough reflections to make up any sort of section.

The work in the Cuyama Valley employed mainly the "H" spread technique with the occasional employment in particularly bad areas of both the "plus" and "H" techniques combined for the purpose of obtaining essentially four different parallel profiles at certain points. In addition, wherever possible, one shot at each station at which an "H" spread was used was recorded as a dual recording with each trace being compounded from the outputs of the corresponding seismometer groups on the two legs of the "H." Such a record has been designated as "D_2H." The "D_2H" records have consistently been found to produce additional reflections which could not normally be obtained from either leg of the "H." A fuller discussion of the "D_2H" technique is intended for the near future.

Figures 8 and 9 show portions of records obtained from "H" spreads in the Cuyama Valley. The principal advantage of the "H" technique is shown on these records since the paucity of discernible reflections indicates quite clearly that usable sections would be almost non-existent if it were not for the additional information yielded by the "H" spreads. In this area, at many shot points, it was found that one side of the "H" was much better than the other but that the "good" side was not always the same one for two adjacent holes. Unfortunately, sections from the Cuyama and other areas in which the "H" spread is currently being used, are not available at present.

CONCLUSIONS

It seems to be clearly established that small displacements of shot holes or of seismometer spreads can produce significant differences in the nature of the reflection records obtained. Although we cannot offer a clear-cut and definitive explanation of the etiology of these phenomena, it is, nevertheless, possible to eliminate as being of secondary import some of the causal factors which *a priori* may have been thought to predominate. Local weathering or topographic heterogeneity would almost certainly have about the same or at least a systematically varying effect on reflections from different depths. The same is true of variability due to the hole depth, nature of material surrounding the charge, and other determinants of the velocity and nature of the impulse produced.

The erratic, more or less random, appearance and disappearance of reflections

in the record pairs obtained leads to the conclusion that local surface or near-surface variations do not enter heavily into consideration. This conclusion is supported by the fact that variations occur both between records taken from the two legs of an "H" spread in which factors of hole and charge are identical for both legs, and between the two records from a "plus" spread in which the seismometers are undisturbed in going from one shot hole to the other. Indications are that phase relationships are not important since the pattern of appearance or of non-appearance of particular reflections in the record pairs studied remains substantially unchanged with variation of the frequency response curves. That is, a pick which appears from one side of an "H" spread but not from the other cannot usually be made to appear on the latter side merely by changing the response curve.

It would, therefore, appear that the above-described phenomena are produced by irregularities in the reflecting interfaces or in the media through which the energy is transmitted; or that, as is too often the case in nature, the variations found are the result of all these and many other causative factors, each playing a microscopic role, but resulting conjointly in a significant effect.* Further study and experiments may result in a clearer insight into the effects of small changes in spread and shot hole locations on reflected energy. From a practical viewpoint there has been achieved, nevertheless, a method of increasing the quantity and degree of certainty of reflections in areas which might otherwise be difficult, if not impossible to work.

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* Mr. S. Meiboom of the Weismann Institute of Science, Rehovoth, Israel, has suggested to me that the phenomena reported here may well be due to a small but definite warping of the reflecting horizons or layers. Such a warping can have the effect of focusing or of dispersing the incident energy. The effect would be most marked when the radius of curvature of the warps is of the order of magnitude of the virtual depth. This theory requires us to envisage a very gentle corrugation of the sedimentary layers, a concept which seems to be reasonable in those areas for which the phenomena were reported.

COMPUTATION CHARTS FOR LINEAR INCREASE OF VELOCITY WITH DEPTH*

W. B. AGOCS†

ABSTRACT

Computation charts are presented which reduce or eliminate calculations of correlation and wave-front depth charts. A series of depth charts are made for particular values of the velocity increment solving the time-depth relation for all possible initial velocities of the equation $y=(Vo/k)(e^{kt}-1)$. From these charts, the average velocity-depth curves are obtained, and also the velocity function to be used on a project determined from velocity shooting by comparison to the theoretical average velocity-depth curves. For wave-front depth charts, a series of families of curves are plotted for the full range of velocity increments and all initial velocities for the equations of the instantaneous center of the wave front, $z=(Vo/k)(\cosh kt/2-1)$, and the radius of the wave front, $r=(Vo/k)(\sinh kt/2)$. The relation between k and $e^{kt/2}$ for a range of times is plotted, and therefrom the value of $e^{kt/2}$ obtained for the particular velocity increment for the solution of the equation $\tan\theta/2=\tan\theta_0/2\cdot e^{kt/2}$. Finally, curves for a series of $\tan\theta/2$ against initial velocity curves are plotted for a series of step out times, and therefrom the value of $\tan\theta/2=\tan\theta_0/2\cdot e^{kt/2}$, or the angle of dip, θ, is obtained. This latter family of curves can be used to determine the variation of dip with variation in initial velocity in highly folded areas. The latter set of curves is useful for the construction of a time-step-out time-dip-depth-offset chart which is used for direct plotting of offset-depth-dip positions of reflecting horizons, or as a trace-analysis underlay chart.

INTRODUCTION

The majority of reflection seismograph depth calculations are based on the linear increase of velocity with depth. The velocity function which is to be used is usually determined from the refraction interval velocity-depth curve, or the average velocity-depth curve by least squares calculation. The interval velocity-depth and the average velocity-depth curves are obtained from well, reflection velocity, or refraction velocity shooting. The correlation depth charts based on the chosen velocity function are calculated, but if the survey is in an area of dips greater than 5°, the necessary calculations are made for time-depth-offset charts.

In order to limit calculations to the minimum, charts have been designed from which the average velocity-depth, the time-depth, center point and radius for wave front charts, and the angle-offset-depth for step out times may be obtained for the condition of linear increase of velocity with depth. The equations used have not been derived since they are standard and may be found in current literature and geophysical texts.

THEORY

The initial condition for the linear increase of velocity with depth is that

$$V_y = Vo + ky. \tag{1}$$

* Manuscript received by the Editor December 5, 1949.

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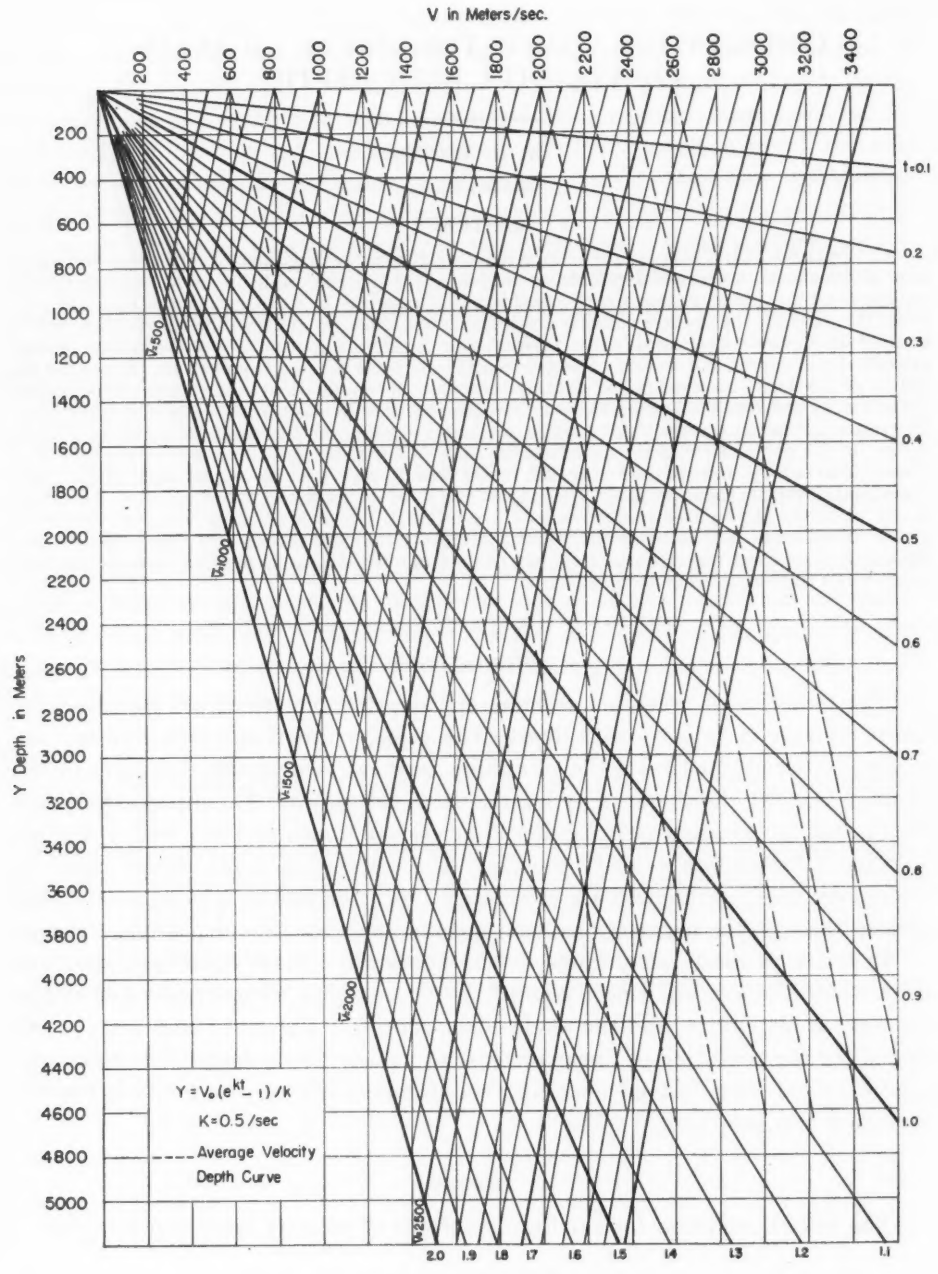

FIG. 1. Correlation time-depth chart with iso-velocity lines, and average velocity-depth curves obtained therefrom.

Where V_y is the velocity at depth y, with the initial velocity being vo, and K/sec being the slope of the equation of the instantaneous velocity-depth line given by equation (1).

For the compressional waves whose rays are normal to the horizontal velocity layers, the travel time to a depth y is

$$y = (Vo/k)(e^{kt} - 1). \tag{2}$$

Equation (2) is the equation of a straight line between y, the depth, and Vo, the initial velocity if a fixed value of k and t are chosen, e is the base of Naperian logs. Figure 1 illustrates the family of curves for a fixed value of k equal to 0.5/sec. For general use, a set of curves such as shown in Figure 1 may be drawn for a range of values of k equal 0.1/sec. to 1.5/sec. in increments of 0.1 which should cover the full range of velocity increments.

Average Velocity Depth Curves.—For the average velocity depth curve

$$\overline{V} = y/t \tag{3}$$

where $\overline{V}$ is equal to the average velocity of a wave to travel to a depth y. The solution of equation (3) may be obtained from the time-depth relations of Figure 1. Iso-velocity lines may be drawn from the initial velocity point (Vo) to the maximum time curve, because the travel time associated with each depth point is given. Hence the average velocity for the point (y, t) is obtained.

The average velocity-depth curve is shown on Figure 1 by the dashed line for $k=0.5$. In Figure 2 the average velocity-depth curves are given for initial velocities of 1,600, 1,800, and 2,000 m/sec for the range of k from 0 to 1.0/sec in increments of 0.1/sec.

The velocity function to be used on a prospect on which sub-surface velocity data are available may be determined by comparison with a series of curves similar to that of Figure 2 in the complete range of initial velocities. These curves could be derived from the charts shown in Figure 1. The average velocity-depth curves obtained from well, refraction or reflection velocity shooting can be plotted on tracing paper to the same scale as the theoretical curves. The direct visual comparison of the experimental curve with the theoretical ones, the velocity function can be determined simply and rapidly. This reduces considerably the preliminary computations.

Curved Path.—The time-depth charts for correlation depth determinations from shot-point to shot-point using the corrected half reflection times at the shot-point geophones as shown in Figure 1 cannot be used for dips greater than 5°. This type of chart is also not useable for trace analysis of center point plotting. Hence, the following series of charts have been developed for the construction of wave front depth charts.

For a reflected wave incident on geophones spaced symmetrically on either side of the shot point, the relation between the emergent ray to the normal, or

the wave front to the horizontal in terms of the measureable parameters is approximately

$$\sin \theta_0 = (Vo\Delta t)/\Delta x \tag{3}$$

where θ_0 is the emergent angle; Vo is the initial velocity; Δt is the difference in

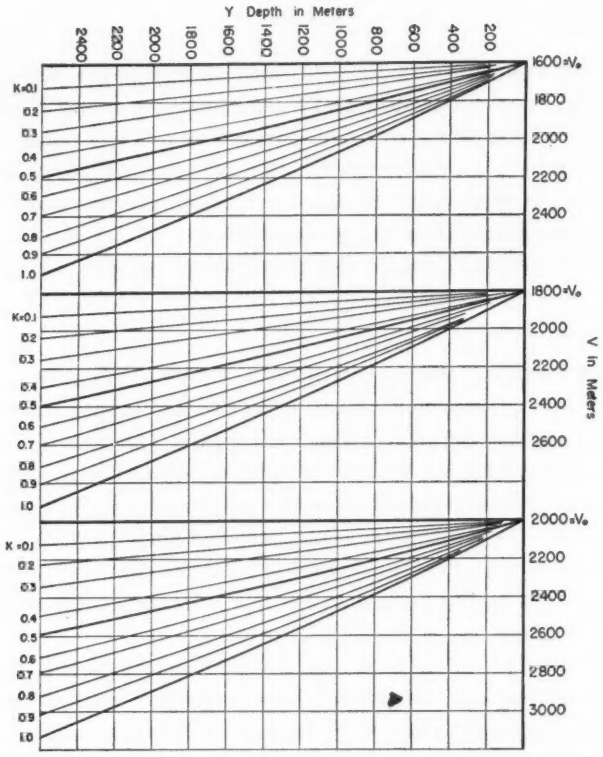

FIG. 2. Average velocity-depth curves for three initial velocities and full range of increments, k.

the corrected reflection times between symmetrically placed geophones separated by a distance Δx, the "split" spread distance.

The equations of the center of the wave front and the radius for it as shown in Figure 3 are related to the following equations:

$$z = (Vo/k)(\cosh kt/2 - 1) \tag{4}$$

and

$$r = (Vo/k) \sinh kt/2. \tag{5}$$

For normal reflections, it may be proven easily that

$$y = (Vo/k)(e^{kt/2} - 1) = z + r = (Vo/k)(\cosh kt/2 + \sinh kt/2 \tag{6}$$

where *t is the reflection time,* and not the half reflection time as used in Equations (2) and (3). From Figure 3, it is seen that OA is equal to z; AB is equal to r.

Equations (4) and (5) are the equations of straight lines if k and t are held constant. Figure 4 illustrates the family of curves from which the center depth and the radius of the wave front may be obtained for k equal to 0.5/sec and the

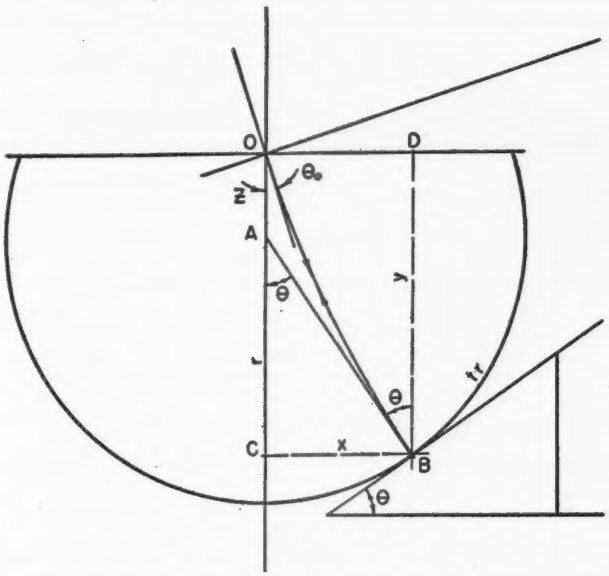

FIG. 3. Wave-front-ray diagram showing reflection from a discontinuity.

initial velocity ranging from zero to 3,600 m./sec. A series of families of curves for z and r may be drawn for the range of k's anticipated to construct the wave front-depth-dip-offset charts. In view of the relations of equation (6) it would be possible to dispense with the curves solving equation (2) as illustrated by Figure 1, except for the fact that they are the source of the average-velocity depth curves.

From Figure 3 it is seen that θ, the normal to the reflecting surface, is tangent to the incident ray, and is also the angle which the radius of the wave front makes with the normal for this angle of reflection, and time t_r. For another wave front at t_r' with its associated center point depth and radius, z and r, respectively, the same angle can be set. The connection of a series of isoclinal points which gives the offset and correct depth can be read from the depth chart for various reflection times. However, the relationship of the measurable parameters of "step-out" time, Δt, per unit split spread, Δx, and reflection time, t_r, to the angle of dip of the reflecting discontinuity must be determined. It can be shown that these relations are

$$\tan \theta/2 = \tan \theta_0/2(e^{kt/2}) \qquad (7)$$

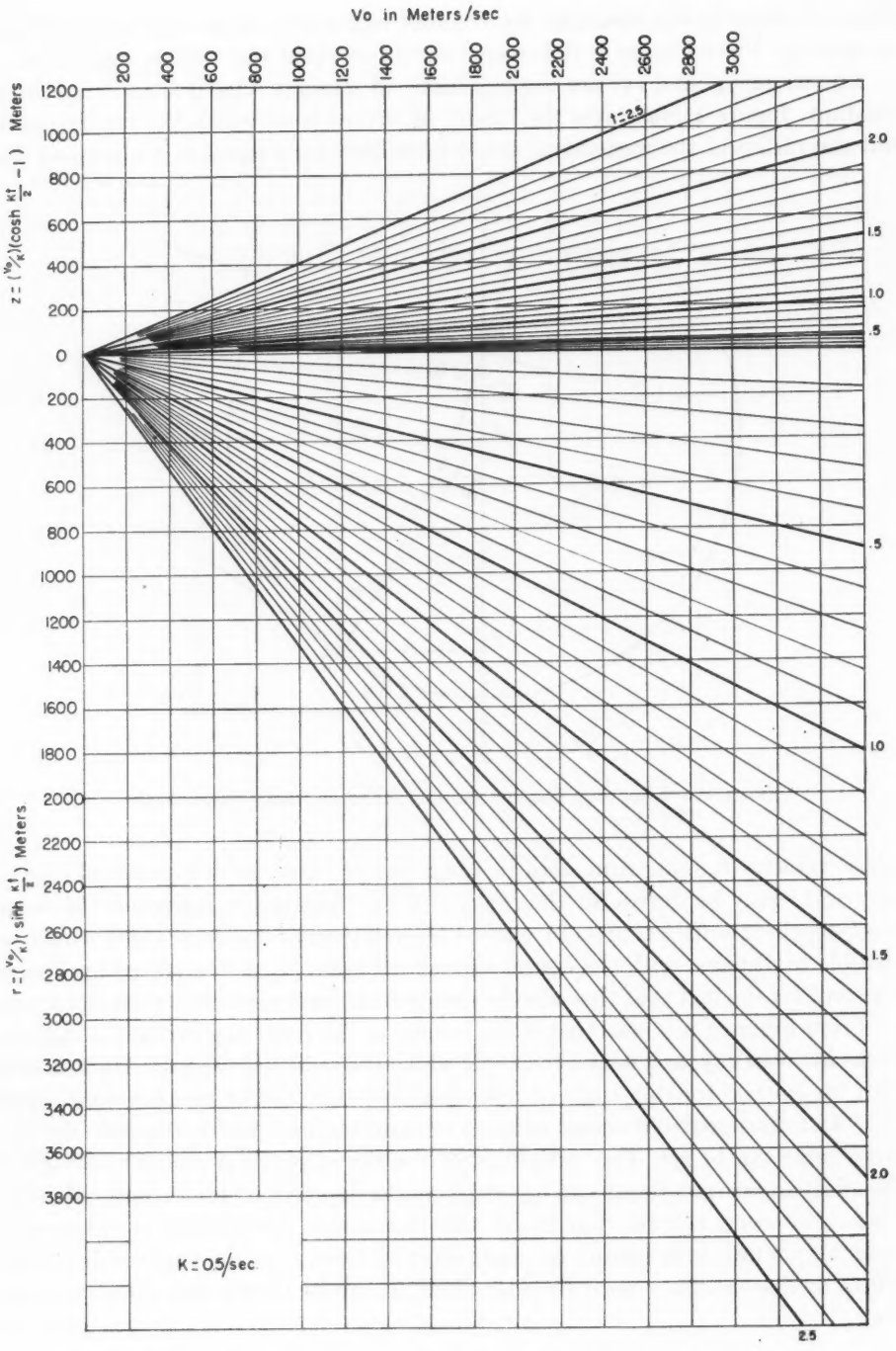

FIG. 4. Center point migration and radius of wave front, time-initial-velocity chart.

where the values θ and θ_0 are the angles shown in Figure 3. It is possible to substitute from equation (3) in equation (7), resulting in

$$\tan \theta/2 = \tan [\sin^{-1} (V\Delta t)/\Delta x]/2(e^{kt/2}). \tag{8}$$

This equation embodies all the observable parameters, and it may be solved uniquely for the angle of the reflecting discontinuity. Furthermore, knowing θ, the solution for the offset, x, and the correct depth, y, (Fig. 3) can be solved by trigonometry and addition. However, all these values may be obtained from the depth chart.

The calculation of wave front-depth charts is simplified by the use of the two standard charts. For a range of reflection time values a family of curves is obtained relating k and $e^{kt/2}$ which are illustrated by Figure 5. For general use, the

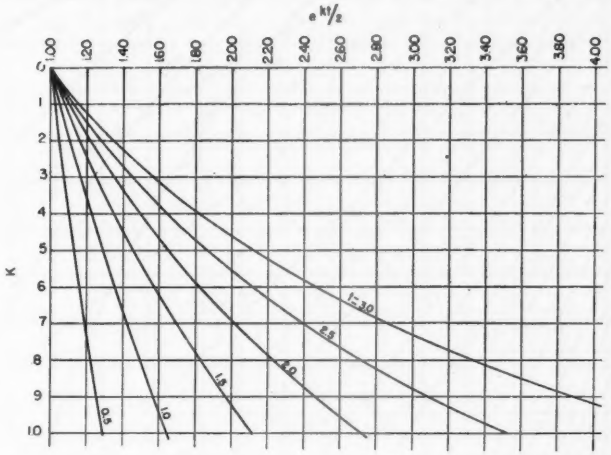

FIG. 5. General chart for relation of $e^{kt/2}$ to k for a series of reflection times.

increments of time can be 0.1 second. From this family of curves, the value of $e^{kt/2}$ for the value of k to fit the velocity function chosen may be obtained for the range of t_r. The relation

$$\tan [\sin^{-1} (Vo\Delta t)/\Delta x]/2(e^{\circ}) \tag{9}$$

is plotted for fixed values of step-out time, Δt, against the range of initial velocities, Vo, for a fixed spread value, Δx. The curves for this equation shown in Figure 6 for a value of 100 meters for Δx. The ordinate values on the left side of the chart are tan $\theta/2$, while the ordinate on the right side is the angular measure of θ in degrees. The top abscissa values are the initial velocities, Vo. The bottom abscissa values are $e^{kt/2}$ for the range shown in Figure 5. The sloping straight lines of Figure 6 represent the value

$$\tan \theta_0/2e^{kt/2}. \tag{10}$$

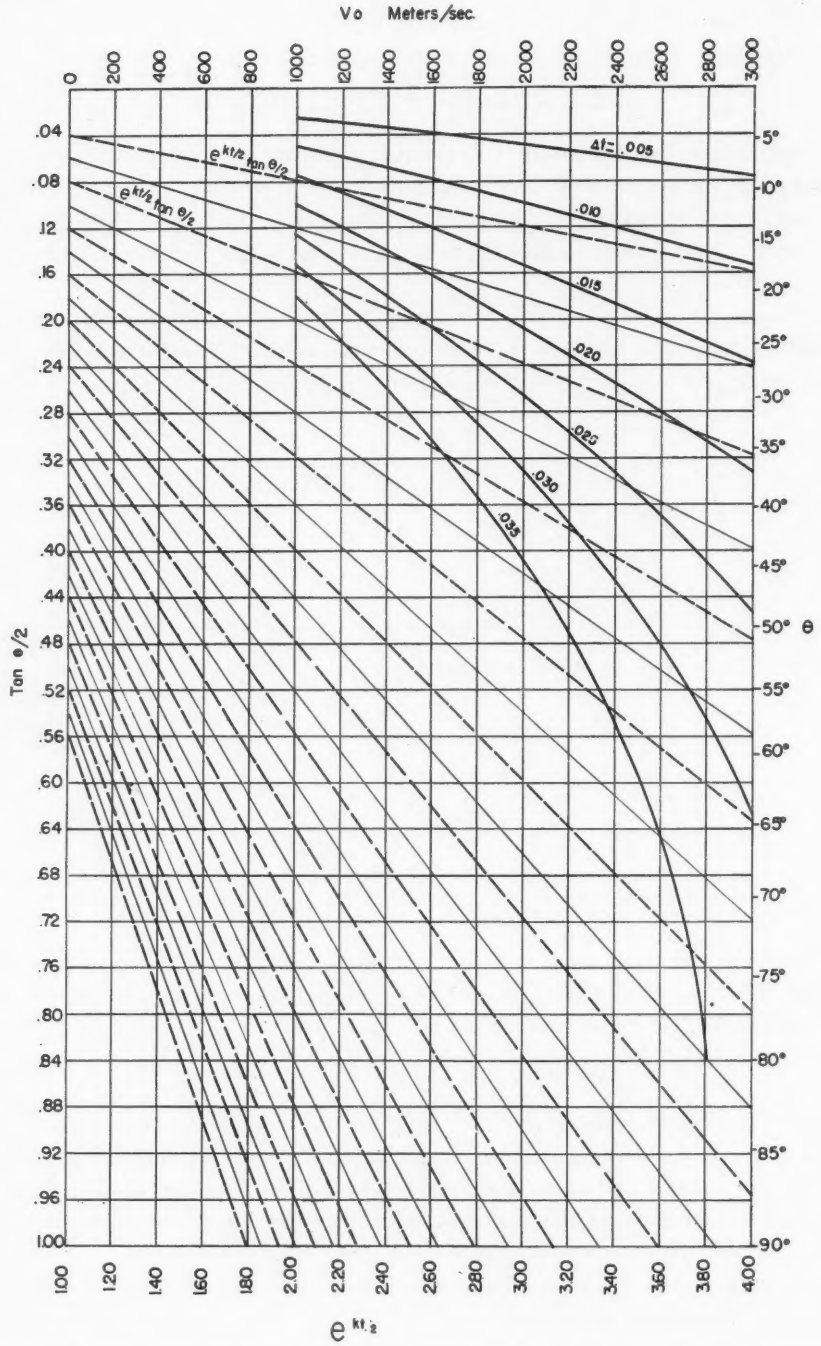

FIG. 6. Initial velocity—tan $\theta/2$ curves, and curves determining $e^{kt/2} \tan \theta_0/2$ and the associated angle of the reflecting horizon.

With a series of families of curves similar to Figure 4, and the general charts of Figures 5 and 6, a time-step-out, time-dip-corrected, depth-offset curve can be constructed similar to Figure 7. The procedure for construction is as follows:

(a) The scale of construction should be equal to the scale of the cross-section used, so that the chart may be used as an underlay chart.

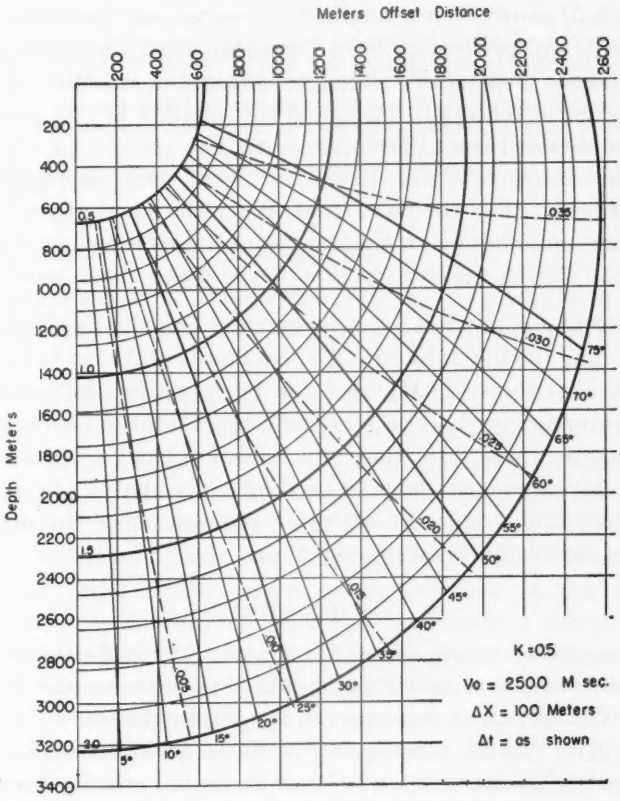

FIG. 7. Wave front time-stepout time-dip-offset-depth chart.

(b) The time interval between reflection isochrons should be ten milliseconds so that interpolation can be made to the nearest millisecond of reflection time.

(c) The migration of the center point for each reflection time, for the chosen initial velocity, Vo, can be obtained from the family of curves for the k fitting the chosen velocity function from the series of curves similar to Figure 4. At the same time the radius of the wave front may be obtained for the same time.

(d) The radius drawn from the center to the associated isochron, or wave front, and the iso-clinal points connected by a smooth curve, will give the

pre-determined iso-clines. These points need to be determined only at five hundred millisecond intervals.

(e) The value of $e^{kt/2}$ for the chosen value of k can be obtained for each five hundred millisecond interval, and ordinates erected for these values on Figure 6.

(f) From Figure 6, the value of equation (9) for the chosen Vo may be spotted for each Δt shown. For example, for $t=0.005$ sec. the value $\tan \theta_0/2 \cdot e^0$ is obtained, and proceeding from this point along the $\tan \theta_0/2 \cdot e^{kt/2}$ line to the ordinate lines for $e^{kt/2}$ determined from (e), equation (8) is solved for the spread of reflection times, and the value of the θ's associated therewith is obtained from Figure 6 directly.

(g) For the chosen reflection times, and from their associated centers, the angle θ is placed on the wave front. When the equal Δt points are marked, they are connected by an equal step-out line as shown on Figure 7. This is the final step in the construction of the depth chart shown in Figure 7.

The Δt's for any split-spread can be corrected to the fixed value for the Δx chosen by dividing the full Δt by the number of units of Δx in the full spread used.

The depth chart shown in Figure 7 can be drawn for the full two quadrants and used as an underlay chart to plot the correct position, with its correct dip, and any reflection whose "Δt" time and reflection time, t, are known. For low angles of dip this same chart may be used for trace analysis by plotting the reflections at their center point or reflection position, since the depth chart will correct for angularity or normal step-out time.

CONCLUSIONS

With the suggested sets of curves the amount of calculation for depth charts based on linear increase of velocity and curved path theory can be reduced to a minimum. With a full set of these curves, the determination of the velocity function to the velocity control, the correlation charts, the construction of wave front charts, and dip variation due to variation of the initial velocity becomes a routine procedure. The dip variation due to variation of the initial velocity can be determined simply and rapidly from Figure 6.

INTERPRETATION OF SPONTANEOUS POLARIZATION ANOMALIES CAUSED BY SPHEROIDAL OREBODIES*

SULHI YÜNGÜL†

ABSTRACT

The theoretical case of a polarized hidden sphere is discussed briefly. To determine location, depth and dip of an orebody displaying natural currents a method of practical value is explained and a master diagram is given. A distinction is made between anomalies which can be treated assuming a polarized sphere and those which can not be interpreted this way. A generalized method of topographical and regional correction is given. The procedure of interpretation and topographical correction is shown with two field examples. The method is not empirical and the results are precise when applied to the cases in which the assumption of a sphere is justified. It is shown that topographical corrections can not be overlooked.

INTRODUCTION

The following is a part of a thesis (Yüngül, 1945) with different examples and additional details. A reference has been made to it in a recent paper by L. de Witte (1948).

By the expression, "spheroidal orebody," is meant an orebody which is not a thin, sheet-like, extended vein or a long, rod-shaped mass, but is a somewhat compact round body, and the cover over it is comparable to its diameter. Under these conditions, to interpret the anomaly caused by spontaneous polarization of such an orebody we can make use of Petrowsky's analysis (1928) of the electric field of a hidden polarized sphere. In reality, when a sphere is assumed, the angle α has to be nearly zero. A spherical orebody has to have its axis of polarization nearly perpendicular to the surface, since the water table is almost horizontal in flat areas, and follows the general trend of the topography otherwise. This is why many negative centers encountered in practice are not accompanied by a positive center. Thus, if an orebody displays a dip angle, it usually means that it is not spherical, but elongated. The assumption of a sphere is still justified, since it is closer to the reality than the assumption of a dipole or a sheet, if the anomaly has the characteristics of one caused by a sphere.

The case of a dipole was analysed by Walter Stern, (1945) and that of a sheet, which is frequently encountered in practice, regular sulphide veins and anthracite beds, still remains but slightly investigated by Edge and Laby (1931), and by E. Poldini (1938).

HIDDEN POLARIZED SPHERE

An infinitely conductive sphere is buried in the ground. Its radius is r, and the depth to its center is h. The sphere is polarized, that is, it develops an electromo-

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tive force which has the greatest value along the axis of polarization, inclined at an angle α to the vertical, and decreases toward the "equator," according to the cosine law. The current thus formed spreads over the whole ground. It is assumed that the ground surrounding the sphere is homogenous and isotropic. The problem is to find the depth, h, the projection of the center on the surface, O, and the angle α. Determination of the radius, r, requires the value of electromotive force, E, which can not be determined precisely. Let us assume a coordinate system on the surface. The origin is at the projection of the center, the X-axis is in the direction of the polarization axis, and the Y-axis is perpendicular to it. The potential at any point on the surface is

$$W = Er^2(x \cdot \sin \alpha + h \cdot \cos \alpha)/(x^2 + y^2 + h^2)^{3/2} \tag{1}$$

and the potential gradient is

$$\overline{F} = \bar{\imath}\partial W/\partial x + \bar{\jmath}\partial W/\partial y. \tag{2}$$

Taking the partial derivative of $\overline{F}$ with respect to X and introducing $u=x/h$, $v=y/h$, we find its projection along the X-axis,

$$F_x = E \cdot r^2[3 \cdot u \cdot \cos \alpha - (1 + v^2 - 2u^2) \sin \alpha]/h^3[1 + u^2 + v^2]^{5/2}. \tag{3}$$

In Figure 1 the potential gradient profiles along the X-axis are shown for three different inclination angles. In this case v is equal to zero. On the axis of the abscissae are plotted the values of u.

In what follows the zero, minimum and maximum points will refer to the potential gradient profiles parallel to the X-axis, if not mentioned otherwise. Each potential gradient profile displays two zero points representing the maximum and minimum potential points on the potential profile, A_1 and B_1, and a minimum point between them, C_1, representing the inflectional point on the potential profile.

Let us take profiles which are parallel to the polarization plane (to the X-axis). The locus of the zero points is

$$u^2 - 1/2 \cdot v^2 + 3/2 \cdot \cot \alpha \cdot u - 1/2 = 0 \tag{4}$$

which is the equation of a hyperbola whose real semi-axis, $A_1B_1/2$, coincides with the X-axis. The asymptotes are inclined to the X-axis at 54 °45′ angles.

The loci of the maximum points are given by

$$1 + v^2 = [2u^2(2 + \tan \alpha \cdot u)]/[1 + 3 \tan \alpha \cdot u]. \tag{5}$$

This has three branches, symmetrical with respect to the X-axis. The middle branch, passing through C_1, has an asymptote parallel to the Y-axis.

A PRACTICAL METHOD OF INTERPRETING

In Petrowsky's analysis, determinations of O, h and α depend on d, the distance between the center of the hyperbola and the point where the asymptote to

the middle branch of the minimum point curve intersects the X-axis. In practice, this middle branch is always an irregular curve, and among the available published field data, it has not been possible to find one example in which an asymptote could be drawn to this middle branch accurately. In the following method only the characteristic points which are easily and accurately obtainable from the field data will be used.

The procedure begins with the smoothing of the equipotential lines of the field

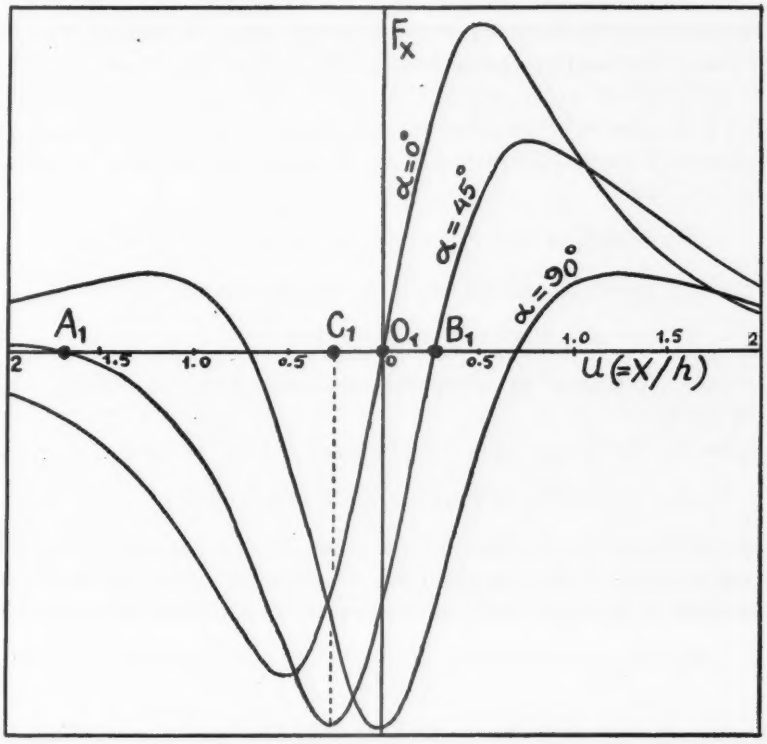

FIG. 1. Potential gradient profiles along the plane of polarization.

data. The straight line between the negative and positive centers can be accepted to be the direction of the plane of polarization which is the vertical plane passing through the axis of polarization. Several profiles are drawn parallel to this line, and on each profile zero and minimum points are marked. The loci of these points are drawn as smooth curves.

Calculations should not be based on a single profile between the negative and positive centers. This is no more than an estimation, first, the assumption of a sphere can not be justified for every field data displaying a negative center; second, quantities measured on a single profile are usually erroneous. A smoothed locus of the characteristic points is necessary.

In F_z vs. x/h curves of Figure 1, what we called A_1, B_1, C_1 will be called A, B, C in the field potential gradient curves, which are F_z vs. X. The method is arranged so that only the absolute values of CB, CA, AB are considered, when the negative center is in the positive direction of the X-axis with respect to the positive center. If the loci of the zero points is a hyperbola whose asymptotes make an angle with the AB line close to 55° on each side, and intersect on the AB line, and if the locus of the minimum points is somewhat a vertical curve which is symmetrical with respect to the AB line, then we are justified to assume a sphere for precise calculations. Anomaly over a negative center is usually much stronger than that over the positive center in sulphide bodies. The branch of the hyperbola over the positive center may not be regular. One good branch over the negative center is satisfactory, the other one serves mainly to locate the point A.

Referring to Figure 1, the ratio C_1B_1/C_1A_1 defines the angle α. In case of a profile along the X-axis,

$$F_z = Er^2[3u \cdot \cos \alpha - (1 - 2u^2) \sin \alpha]/h^3[1 + u^2]^{5/2}. \tag{6}$$

To find the zero points A_1 and B_1, we have, after arranging,

$$2 \tan \alpha \cdot u^2 + 3u - \tan \alpha = 0. \tag{7}$$

Giving values to α from 0° to 90° we obtain a series of O_1B_1 and O_1A_1 values, two for each α value.

Likewise, for the maximum points along the X-axis, we have

$$2u^3 \cdot \tan \alpha + 4u^2 - 3 \tan \alpha \cdot u - 1 = 0. \tag{8}$$

Again, giving values to α, we obtain three values of u for each value of α, and as we are interested in the minimum point, C_1, we take the middle value alone, O_1C_1.

From these, C_1B_1, C_1A_1, O_1B_1, and A_1B_1 values are calculated. Here we note that

$$A_1B_1 = AB/h \tag{9}$$

$$O_1B_1 = OB/h \tag{10}$$

$$C_1B_1/C_1A_1 = CB/CA. \tag{11}$$

Table 1 shows these values for nine different α values. In Figure 2 these are

TABLE 1

α	AB/h	OB/h	CB/CA
0°	∞	0.0000	0.00000
5°	17.2005	0.0288	
10°	8.6243	0.0583	
15°	5.7749	0.0879	0.09622
30°	2.9578	0.1800	0.21256
45°	2.0614	0.2807	0.35262
60°	1.6582	0.3961	0.52241
75°	1.4701	0.5341	0.73150
90°	1.4142	0.7071	1.00000

plotted with different scales on the X-axis and a common scale on the Y-axis for α. The use of this diagram is simple and expeditious. First, CB/CA is found from the field data. The vertical line from CB/CA value on the X-axis intersects the CB/CA curve at a point from which a horizontal line intersects the Y-axis, AB/h and OB/h curves, giving α on the Y-axis and the AB/h, OB/h values on the X-axis. Measuring AB on the field data we have h, and then OB which gives the location of the center.

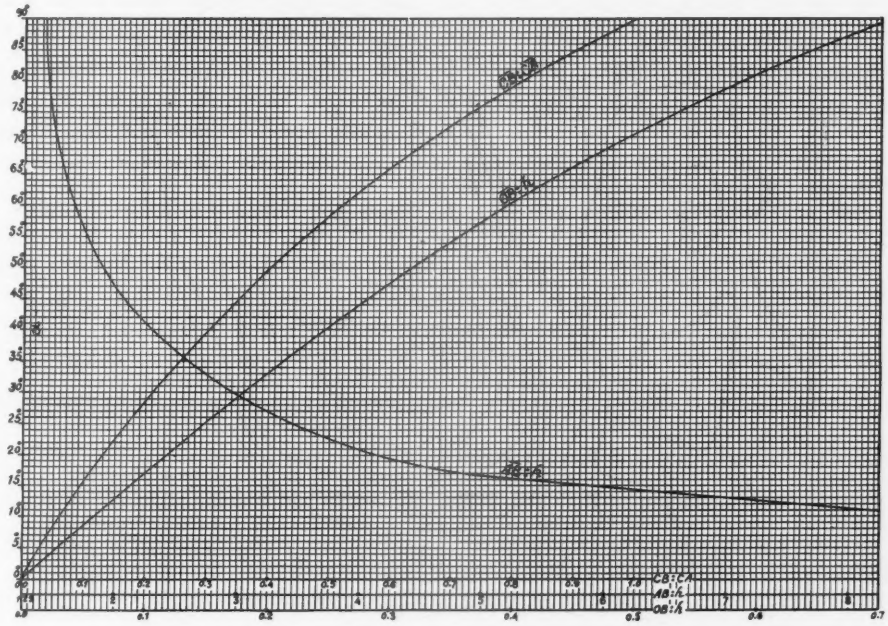

FIG. 2. Interpretation diagram, spontaneous polarization of spherical bodies.

If the sphere is polarized vertically, that is, $\alpha=0°$, B is right above the center and A is at infinity (see Fig. 1). If there is no positive center, and the negative center is formed of concentric circles, the locus of the zero points is reduced to a straight line passing through B, along profiles in any direction. Then $\alpha=0°$, $h=2|CB|$, and B coincides with O. When $CB/CA=1$, the sphere is polarized horizontally, and $\alpha=90°$, C coincides with O, and $h=AB/1.414$.

Determinations thus made refer to the surface, that is, the depth h is the perpendicular distance from the center to the surface, and is not vertical, if the surface is not horizontal. Alpha is the angle between this perpendicular and the axis of polarization. The location of the center is the projection on the surface and not on the horizontal. Corrections concerning this fact will be discussed in the following topic.

The necessary data are obtained from the equipotential lines. Inflectional points on the potential profiles are found by drawing them on millimeter paper

and counting vertical squares for a fixed horizontal distance. Although potential gradient profiles may be found directly in the field taking potential difference readings at equal electrode separations and dividing by the spread we can not make use of this fast method, because the direction of the plane of polarization must first be known.

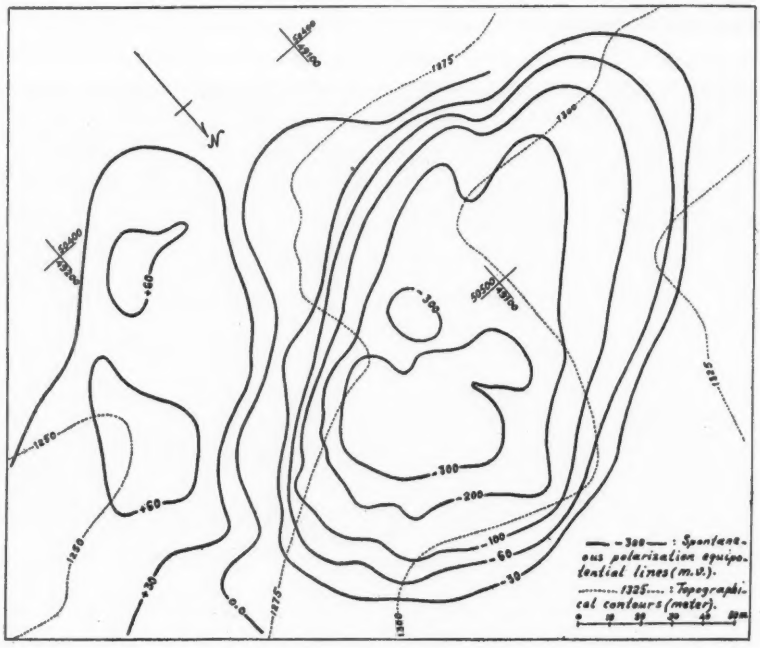

FIG. 3. Weiss anomaly, Ergani, Turkey.

TOPOGRAPHICAL CORRECTIONS

Many phenomena enter into this subject whose underlying cause is topography. For example, negative contours are elongated toward hills because descension of rain water creates negative centers on hill tops due to electrocapillary action (see Fig. 3). Also telluric potentials vary with elevation. These types of effects are difficult to deal with. Here only the descriptive corrections will be discussed, as previously mentioned. They are quite large when the surface is steep. Determinations of h, α and O were made assuming the surface as a horizontal plane. When a map is made the original potential distribution is projected on a horizontal plane. A logical correction method would be to transfer every point on the map onto the surface plane, then to smooth the potential contours and to determine the zero point hyperbola etc.. However, this would not be practical since it is usually impossible to pass a plane which would follow the surface closely over the whole anomaly area.

A, B, C, h, α, O refer to the map, that is, to the horizontal plane; A', B', C',

h', α', O' to the surface plane which is not horizontal. After corrections: h'' is the vertical depth from the surface plane, α'' is the angle between the vertical and the polarization axis, and O'' is the location of the center on the map.

The map gives the projections of $C'B'$, $C'A'$ and $A'B'$ distances as accurately as desired. Only in the region of the AB line can a surface plane be passed, and the real distances $C'B'$, $C'A'$ and $A'B'$ on the surface are found. The effect of topography on the rest of the anomaly, or rather, on the shape of the anomaly is taken care of to some extent by smoothing the equipotential lines and the loci of the characteristic points.

θ is the slope angle of the surface plane, and δ is the slope angle of the $A'B'$ line. As the explanation of this descriptive geometry problem will take too much space, only the results will be given.

$$h'' = h/\cos\delta \cdot \cos\theta \tag{12}$$

$$OO'' = h \sin\theta/\cos\delta \tag{13}$$

where OO'' is perpendicular to the strike of the surface plane and in the direction of up-hill.

$$\sin\alpha'' = O''M \cdot \cos\alpha \cdot \cos\delta/h \tag{14}$$

where the point M is found from

$$OM = h \tan\alpha, \tag{15}$$

and is in the direction of the negative center B. $O''M$ is measured and placed in equation (14) (see Fig. 4).

If the polarization axis is perpendicular to the surface, that is, $\alpha = 0°$, a profile perpendicular to the strike of the surface plane is taken. Thus we have $\theta = \delta$, and

$$h'' = h/\cos^2\theta \tag{16}$$

$$OO'' = h \cdot \tan\theta \tag{17}$$

$$\alpha'' = \theta \tag{18}$$

where the polarization axis is pointing down hill.

REGIONAL CORRECTION

This is another correction which can be generalized and obtained in a direct manner. Regional potentials are due to what generally is called "telluric currents" and may amount to 100 millivolts per kilometer or more. They are determined by surveying a comparatively large area around the anomaly and smoothing the anomalous part. The correction can be made in a similar manner to that used in gravity interpretations. If the regional gradient is, or is assumed to be, uniform in the anomalous region the corrected positions of A, B, and C are easily determined by shifting the X-axis up and down by an amount equal to the regional gradient in the direction of A to B, thus finding the new locations of the intersec-

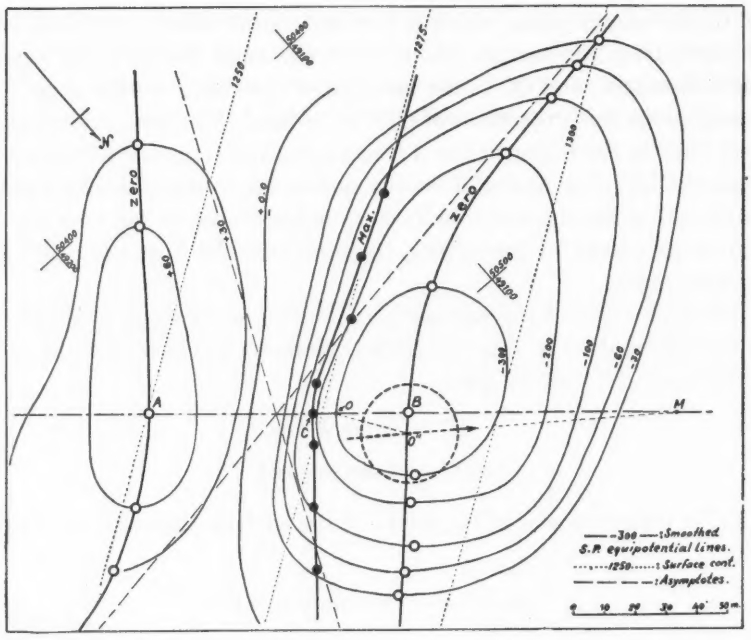

FIG. 4. Weiss anomaly, Ergani, Turkey.

tions of the X-axis with the potential gradient curve. The minimum point, C, remains the same.

If the regional gradient is positive, that is, the potential increases in the direction of A to B, it must be subtracted. This is achieved by shifting the X-axis upward with an amount equal to the uniform gradient. This operation causes the AB distance to expand. Otherwise the X-axis is lowered and the AB distance is shortened. Regional corrections should be eliminated before topographical corrections and included in the A' B' distance.

EXAMPLES

The following examples, Weiss and Süleymanköy anomalies are in the Ergani copper district, 65 kilometers S. E. of Elaziğ in eastern Turkey. The Weiss anomaly is one kilometer N. W. of the Maden Copper Mine where at present an open cut mining is being conducted.

Weiss Anomaly

Figure 3 shows the potential distribution and the surface topography. Figure 4 is obtained after smoothing the equipotential lines. Dotted lines are the contours of the surface plane. Empty circles are the zero-points and the full circles are the minimum points obtained on profiles parallel to the line passing through the negative and the positive centers. Broken lines are the asymptotes to the zero-point hyperbola.

From the data: $CB/CA = 31/54 = 0.574$, $AB = 85\ m.$

From Figure 2: $\alpha = 64°$, $AB/h = 1.58$, $OB/h = 0.432$.

We calculate $h = 53.8$ m., $OB = 23.2\ m.$ These values of h, α, and OB would define the orebody if the surface was nearly horizontal. In this case the surface plane makes a large angle, 24°30′, with the horizontal.

Topographical Corrections.—$\theta = 24°30'$, $\delta = 23°40'$. $h'' = 64.6$ m. is found from equation (12); $OO'' = 24.35$ m. from equation (13); $OM = 110.8\ m.$ from equation (15); $O''M = 87m.$ by measuring; $\alpha'' = 40°30'$ from equation (14). After topographical corrections the new location of the orebody center is O'', the plane of polarization is shown by the arrow which indicates the direction of the polarization axis and the upper (negative) pole.

Süleymanköy Anomaly

Figure 5 shows the equipotential contours. The results are:

$CB/CA = 23/36 = 0.639$, $AB = 59\ m.$

$\alpha = 69°$, $AB/h = 1.52$, $OB/h = 0.472$

$h = 38.8\ m.$, $OB = 18.3\ m.$

Topographical Corrections—The strike of the surface plane is N 84° E, the dip $\theta = 16°30'$ N, and $\delta = 9°50'$.

$h'' = 41.8\ m.$, $OO'' = 11.2\ m.$, $OM = 101.1\ m.$, $O''M = 108.0\ m.$, $\alpha'' = 79°$.

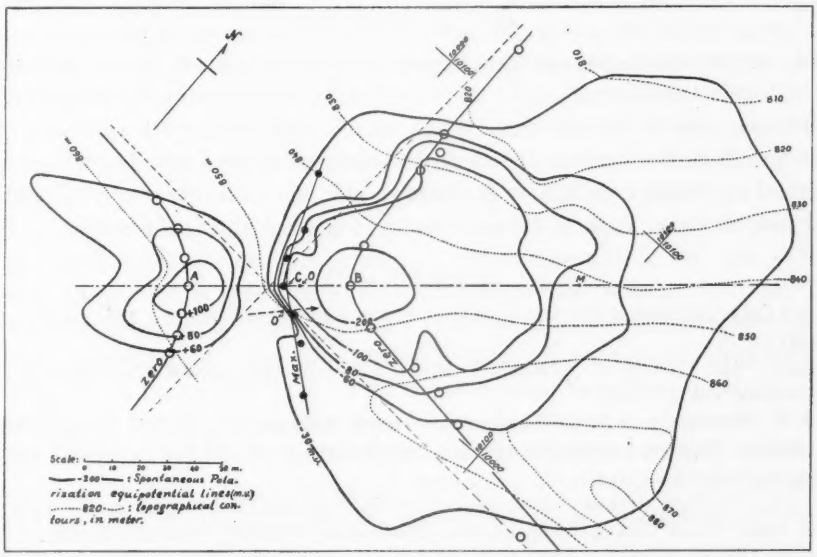

FIG. 5. Süleymanköy anomaly, Ergani, Turkey.

CONCLUSIONS

The assumptions are close to reality because they are controlled. The quantities obtained from the field data are such that they are easily and accurately measurable. This method does not require absolute potential values, and rate of

change of potential is treated without the use of a base line or zero potential points.

From Table 2 one observes, that it is easy to miss a large orebody by exploration drilling, if no topographical corrections are made, when the surface has a large slope.

TABLE 2

	Before Topogr. Corrections	After Topogr. Corrections
	Weiss Anomaly	
Depth	$h=53.8$ m.	$h''=64.6$ m.
Inclination	$\alpha=64°$	$\alpha''=40°30'$
Location		$oo''=24.3$ m.
Polarization Plane		horizontal shift 5 degrees rotation
	Süleymanköy Anomaly	
Depth	$h=38.8$ m.	$h''=41.8$ m.
Inclination	$\alpha=69°$	$\alpha''=79°$
Location		$oo''=11.2$ m.
Polarization Plane		horizontal shift 4.5 degrees rotation

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THE METEOROLOGICAL AND OCEANOGRAPHIC ASPECTS OF GEOPHYSICAL PROSPECTING*

ALFRED H. GLENN† AND CHARLES C. BATES‡

ABSTRACT

The systematic application of the sciences of meteorology and oceanography to geophysical exploration problems is proposed as promising on the basis of successful experiences with these sciences in production operations. Potential applications are outlined wherein professional use of meteorology and oceanography proves superior to traditional dependence upon generalized governmental information or the hope that management will accept all losses resulting from environmental variations as acts of God. Exploitation of recent oceanographic advances in the revision of present sedimentation theories is suggested with the immediate aim of improving the understanding of stratigraphic traps and reefs.

INTRODUCTION

The production departments of a number of oil companies first applied the geophysical sciences of meterology and oceanography to the design of offshore drilling platforms and to the forecasting of ocean wave conditions which markedly affect the safety and efficiency of offshore operation. A recent paper by Pennington and Posgate, (1949), indicates that the latter application of the two sciences is now of established utility. Since the use of geophysical sciences is normally considered to fall in the domain of petroleum exploration, the following paper discusses certain potential applications of meteorology and oceanography in the work of the exploration geophysicist.

In offshore exploration, high waves, and in onshore exploration, mud and low temperatures, are primary sources of lost time. Exploration can be directed with greatest efficiency when the best information is available regarding such critical weather parameters. The problem is how to obtain such information. At the present time, there are several types of weather forecasting services available. The best publicized is that furnished by governmental weather bureaus. In the United States, however, there is a trend away from a governmental monopoly in weather services since there is a growing body of professional meteorologists operating on a consulting basis. This development, described by Bates (1949), has resulted in recent years in the organization of the National Association of Industrial Meteorologists, the professional association of consulting meteorology. In addition, as with other professions, there are a few vociferous quacks with little or no scientific training who promote their alleged meteorological services on a high-pressure basis, usually conveniently a long distance away from their "laboratories."

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GENERAL WEATHER FORECASTS

Since there is considerable misunderstanding as to what the role of the professional consulting meteorologist is in relation to the Weather Bureau, it might be well to discuss this point. The Weather Bureau is committed to a forecasting policy designed to maintain the safety and economic welfare of the *general* public. In the preparation of forecasts and weather warnings, the Bureau faces the problem of providing an acceptable service to groups of widely divergent interests. If forecasting were a science in which subjective professional judgment were not a factor, this would be no problem. But, consider for example, the dilemma facing the public forecaster who is debating whether to issue tropical storm warnings on the basis of scanty data (a not unusual circumstance in such ocean areas as the Gulf of Mexico) during a holiday weekend. If he issues a storm warning and the storm fails to materialize, beach resort owners realize a heavy financial loss and condemn the Bureau for unnecessarily encouraging tourists to leave the coast. On the other hand, if he does not issue warnings and the storm materializes, he is condemned by fishermen and offshore oil operators for failing to issue warnings far enough in advance for proper precautions to be taken.

If a company has large sums of money at the mercy of weather conditions, it is not advisable to depend on a forecasting service designed as a compromise for solving many weather problems simultaneously. The solution is the employment of a company or consulting meteorologist who is solely concerned with and is thoroughly acquainted with the problems of the company and can confidentially interpret the significance of each weather situation. The governmental weather services recognize this to be the case and have set up arrangements whereby the private meteorologist obtains government licenses to receive weather communication facilities available in his area, like U. S. Weather Bureau teletype circuits, Air Force-Navy-Weather Bureau facsimiles, et cetera, with the understanding that the consultant's advices are available solely to his clients on an ethical, confidential basis.

The consulting meteorologists have concluded an agreement* with the U. S. Weather Bureau defining the field of governmental weather service to be general weather service for insuring the safety and welfare of the public and the field of consulting meteorology to be confidential service for the maintenance of efficiency and safety in specialized business, agricultural, or industrial activities involving high weather risk. Because consulting meteorology is a relatively recent development, there is at present some duplication of functions between the consulting and governmental meterologists and an effort is being made by the American Meteorological Society to eliminate this.

* Statement of relationships between U. S. Weather Bureau and industrial consulting services as a result of discussions held in Washington, D. C. March 30 and 31 and June 28, 1948, with the Chief, U. S. Weather Bureau and Representatives of Industrial Weather Consulting Services and the American Meteorological Society: Minutes of the Committee on Industrial Business and Agricultural Meteorology: American Meteorological Society.

Over the past twenty years, there has been a relatively small improvement in the accuracy of general "area" forecasts prepared twenty-four to forty-eight hours in advance. Short range forecasts of conditions in various states and coastal or ocean areas which are widely distributed are intended to give a generalized picture of conditions throughout the area. Obviously, a forecast of conditions over large areas cannot be very specific simply because such conditions as wind, precipitation, and temperature vary so widely within short distances.

SHORT RANGE FORECASTS

However, during the past ten years, there has been a vast improvement in the accuracy of short range forecasts for a specific location. It can be stated with re-

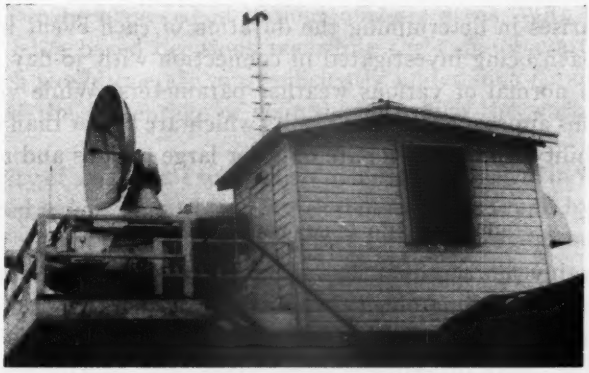

FIG. 1. Meteorological station at Grand Isle, Louisiana, equipped with 10-cm weather radar and standard meteorological instrumentation. Established for improvement of accuracy in weather and wave forecasting for offshore oil operations.

liability that short range forecasts up to forty-eight hours in advance can be prepared today with a high order of accuracy for any location in the world providing the meteorologists can be furnished with the local observing facilities required. To provide accurate wave forecasts for the offshore oil operators in the area from Breton Sound to Timbalier Bay in the Gulf of Mexico, it has been necessary to supplement the governmental weather data ordinarily available with a network of seven offshore weather and wave reporting stations on oil rigs and an observation station (Fig. 1) at Grand Isle, Louisiana, equipped with a 10-centimeter, long range, weather radar, and complete meteorological instrumentation (Glenn and Graham, 1949). With these facilities, forecasts can be provided which are economically justifiable, not only of such spectacular and dangerous weather conditions as line squalls, northers and hurricanes, but also of conditions which affect the overall efficiency of offshore work day by day. Generally speaking, the provision of such forecasts requires an appreciable financial outlay which can be best handled by a joint participation of several companies with a common weather problem.

LONG RANGE FORECASTS

In the realm of long range forecasting of specific meteorological elements at a specific time and location, the science of meteorology is still in the research stage and has little to offer at present. Occasionally a weather pattern is established in the upper atmosphere which permits reliable forecasting for periods up to a week in advance but such an occurrence is not frequent enough to be of continuing economic importance. Although many claims regarding the accuracy of such forecasts for a month of so in advance have been made, the alleged successes are the result of playing probability rather than a demonstration of actual scientific forecasting techniques. The problem in long range forecasting is to time the sequence of weather conditions accurately. Although it is relatively easy to determine what the sequence of weather events will be over a four to seven day period, the difficulty arises in determining the duration of each event in the sequence. Another approach being investigated in connection with 30-day forecasts is the deviation from normal of various weather parameters. While verification tests indicate that this approach is giving results which are better than expected on the basis of probability, the forecasts are only for large regions and not practical for spot planning.

SPECIALIZED CLIMATOLOGICAL STUDIES

Of considerably more utility than the long range forecast for planning purposes is the specialized climatological study. During World War II, meteorologists developed a method of solving climatological problems which is superior to the typical "average" data on temperatures, winds, and precipitation for planning military operations. This technique described by Jacobs (1947) utilizes punched cards. When a particular military operation was planned, the combined factors which might affect its success were determined. For example, an amphibious assault might have required waves less than two feet in height, wind speeds less than ten miles per hour, and visibility in excess of ten miles occurring at the same time. It would be an impossibility to deduce how frequently such conditions could be expected to occur simultaneously from standard climatological tables, but it is a simple matter to run a study of this type if punch card observations from the area concerned are available. There are *over one hundred and fifty million weather observations now on punch cards* for locations throughout the world which are available through various governmental agencies: i.e., Weather Bureau, Air Force, Navy, et cetera.

The possibilities are practically endless for using these data to estimate costs incurred by lost time due to weather or to determine the feasibility of certain land, air, and sea operations. Nevertheless, few industries even know of the existence of these card libraries, fewer have made use of them, and still fewer have utilized the skill of an industrial meteorologist in planning an approach to the sorting problem which will extract the maximum possible information from the cards. In addition, the National Archives and other agencies in Washington have files of

extensive weather records which were not obtained under the auspices of the official weather reporting services but are available to those familiar with the material, and can be processed for punch card use.

Generally speaking, it develops that the most successful applications of meteorology involve a combination of the specialized climatological study for long range planning, short range forecasting for planning day-to-day operations, and instrumentation to maintain accuracy in forecasting and to determine quantitatively the effect of weather on the work. For example, when geophysical operations on the continental shelf were contemplated, geophysical contractors and exploration departments entered a new realm and could have profitably engaged the services of a scientist familiar with the problems of a marine environment. Such a consultant could have provided a quantitative estimate of fog, wave, and wind conditions to be expected in various offshore areas. With such data, the planners could have based decisions regarding the type of craft and auxiliary equipment which would operate most efficiently under such conditions and also have determined the percentage of time during which the work could be conducted.

The sensitivity of small craft to what seem minor differences in wave conditions to the uninitiated is very important. For example, it was found by one organization that a type of motor launch only ten feet shorter than another type was entirely unsuited for winter work, even though the larger type operated satisfactorily. Because of poor equipment planning, the amount of field work fell below what had been anticipated. In another case, it was found that an extremely windswept body of water could be worked much more easily by conducting operations between mid-night and about 9:00 A.M. rather than during standard working hours.

Selection of proper anchors and holding tackle is vitally important, and reliable data could have been obtained concerning the worst possible wave conditions in which this type of equipment would have to operate satisfactorily. Many of the losses of landing craft in the storm on the Normandy beach-head during June, 1944, are attributed to the fact that the holding tackle was too light for the wave conditions which occurred, (Bates and Fleming, 1947).

Proper scheduling of work areas can also save considerable sums. A recent study shows that while wave conditions generally improve along the Texas coast during the summer months, the improvement is significantly greater and occurs earlier in the spring at locations east of Galveston than at locations southwest of Galveston. Figure 2 shows the variation in the frequency of wave heights of four feet at two locations. The location southeast of Galveston shows steady improvement from February to August while the location near Freeport shows no appreciable improvement until June. Obviously, geophysical work in this area could be most effectively carried on in the spring southeast of Galveston and during the summer southwest of Galveston. The explanation of this difference in characteristic wave conditions is relatively simple, involving the wind distribution on the

periphery of the Mexican "heat low" pressure area, and the monetary importance of such information to planners is obvious when one considers the cost of operating geophysical parties offshore.

After planning the operation, the work is turned over to the field supervisor for execution. Here the consultant is in a position to provide specialized short range forecasts and work directly with the party chiefs who must schedule work for maximum efficiency and safety. During the past year, wave heights have been forecasted to the nearest foot and a half at specific locations in the Gulf of Mexico month after month between seventy-eight and ninety-nine percent of the time,

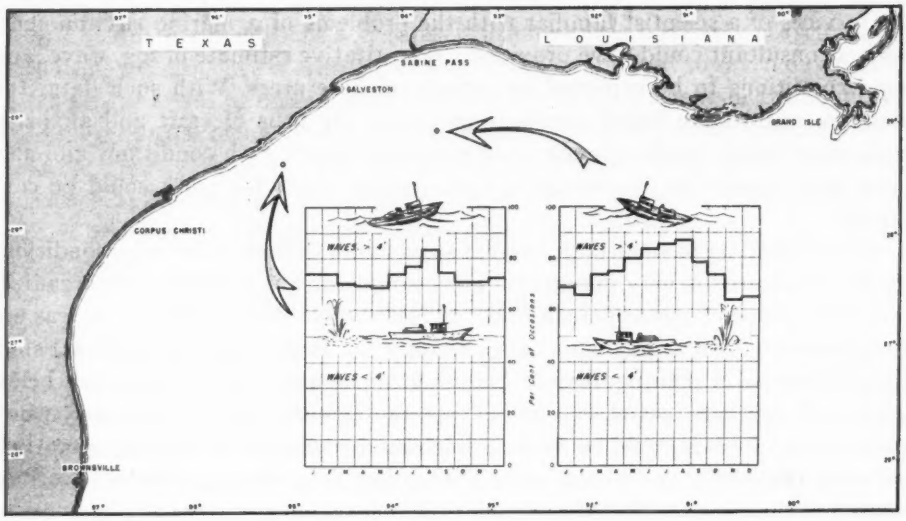

FIG. 2. Variation in mean frequency of occurrence of average wave heights greater and less than 4 feet at two locations in the northwest Gulf of Mexico.

with an overall average of ninety-one percent (Pennington and Posgate, 1949). Since certain small craft are highly efficient in waves two feet high and practically useless in waves greater than four feet, such refined forecasts could have been of definite assistance to party chiefs and field supervisors. These relationships are summarized in Table 1. Meteorology can also be of considerable aid in planning exploration on land, particularly when operations are being planned for a region about which little weather "know-how" has been acquired. After field operations have progressed for a year's time in any region, it is probable that enough mistakes have been made to permit a determination of how operations should be designed to reduce losses caused by weather. The problem is to plan in advance so that the first year's losses will be at a minimum.

Soil trafficability is generally one of the chief problems to be considered along these lines. Fortunately, soil maps of varying degrees of detail exist for many portions of the world (Bates and Glenn, 1947), and new ones are continually being

TABLE 1.* VERIFICATION OF WAVE FORECASTS FOR GRAND ISLE, LOUISIANA AREA

Forecast Period	Error in Feet													No. of Occasions
	−2.0	−1.5	−1.0	−0.5	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	
	Percentage Frequency of Occurrence														
November, 1948															
Morning Forecast 6 A.M.–6 A.M.	1%	5%	6%	15%	29%	18%	16%	7%	2%	2%	1–	—	—	—	121
Evening Forecast 6 P.M.–6 P.M.	1%	2%	4%	3%	34%	22%	18%	3%	7%	2%	2%	1%	1%	1%	121
May, 1949															
Morning Forecast 6 A.M.–6 A.M.	1%	2%	4%	13%	39%	22%	14%	5%	—	—	—	—	—	—	125
Evening Forecast 6 P.M.–6 P.M.	—	—	3%	11%	41%	28%	13%	3%	—	—	1%	—	—	—	125

* Summary of the accuracy of wave forecasts prepared for an offshore location south of Grand Isle, La. The error distribution shown is obtained by comparison of average wave heights forecasted 6, 12, 18, and 24 hours in advance and subsequent wave observations at the same intervals at the location.
(November, 1948, is shown as a month when overall accuracy of forecasting, compared to the entire 1948–1949 period, was relatively low because of rapid changes in wind conditions. May, 1949, is shown as a month when overall accuracy of forecasting was relatively high because of slow changes in wind and wave conditions permitting persistent forecasting.)

prepared in manuscript form. When such maps are used in conjunction with road and topographic maps, with the proper type of rainfall data, and with information on trafficability such as that shown in Table 2, it is possible to map out in advance the most efficient method for shooting an area the size of a county or larger, administrative and lease requirements permitting.

TABLE 2.* EFFECT OF WEATHER ON TRAFFICABILITY

Soil Unit	Short, Heavy Rain (about 0.5″)		Prolonged Rains (2–3 days; over 0.5″ per day)		Alternate Freezing and Thawing
	Trafficability During Rain	Ground Trafficable After Rain in:	Trafficability During Rain	Ground Trafficable After Rain in:	Trafficability
Sandy or gravelly soil on moderate slopes	Fair	2 Hours	Fair to Good	0–8 Hours	Fair to Good
Sandy or gravelly soil on gentle slopes	Fair	2–6 Hours	Fair	4–8 Hours	Fair to Good
Loamy soil on gentle slopes	Poor	8–24 Hours	Fair to Poor	1–2 Days	Fair to Poor
Loamy or clayey soil on moderate slopes	Poor	1–2 Days	Very Poor	1–4 Days	Poor to Fair
Clayey soils on gentle slopes	Very Poor	1–4 Days	Very Poor	2–8 Days	Very Poor
Poorly drained soils other than peat or muck	Trafficable only when frozen in winter and during prolonged dry periods in summer.				
Swamps, largely peat and muck.	Impassable to normal type vehicles except when frozen.				
Various soils on steep slopes (above 25%)	Normal type vehicles must remain on roads.				

* A soil trafficability scale developed for planning military ground operations in World War II. Reprinted with permission of the American Meteorological Society from "Wartime Developments in Applied Meteorology." Meteorological Monograph No. 1, 1947.

The need for such advanced planning was indicated to one of the authors while participating in a seismograph survey in a southern state some years ago. The crew was the first to enter the state at the time, and work was planned to cover a considerable area. Shooting started in late summer and centered around a hilly

area with good drainage and sandy soils. After Indian Summer passed with practically drouth conditions, the work shifted to lowlands in the Selma Chalk. Winter rains turned the black soil into a virtual quagmire, and only about a third as many holes were shot as during the preceding months when travel had been at a normal rate. In addition the vehicles were placed under extreme stress, and lost time from breakdowns and repairs was a common occurrence. Had the areas been worked in reverse order, the lost time due to poor trafficability would, of course, not have miraculously vanished, but the exploration program for the area would have been speeded up appreciably and the equipment would have been much longer-lived.

Temperature is also effective in slowing field work, as has been shown by Burton and Thomsen (1949). When the case is extreme, as with field work being done in the Naval Petroleum Reserve Four in northern Alaska, modifications can be made to equipment, clothing, and operational techniques which permit regular operations to continue down to temperatures near −50°F., even though the unwinterized crew begins to be inefficient at temperatures near 0°F. When geophysical crews are working in other types of severe climates, such as in deserts or humid tropic areas, attention should be paid to providing suitable quarters, air-conditioning, clothing, and specially modified equipment. The extensive work of the Army's Quartermaster Corps has indicated that there is room for considerable improvement in covering the human machine so as to achieve top efficiency. The recent paper "Clothing for Global Man" (Lee and Lemons, 1949) is an up-to-date progress report on developments in this field.

Cooperative studies by the meteorologists and physiologists are indicating what to expect of man when placed in a new and extreme environment. As an example of the findings available to the careful planner, the results obtained by Schickele (1947) concerning the relationship between environment and fatal heat stroke in the Army during World War II are worth citing. With only a few exceptions, all of the deaths in the United States occurred in the South or in the California-Arizona desert and were experienced by overweight individuals from states north of the Potomac and Ohio Rivers who had spent less than two months in the hot climate. Moreover, most fatalities which were associated with heavy exercise came at relatively low temperatures.

SPECIAL OCEANOGRAPHIC APPLICATIONS

A problem of interest to the geophysicist involving the field of oceanography is that of microseisms produced by storms causing interference patterns of waves on the ocean's surface. These interference patterns cause pressure fluctuations to be transmitted to the ocean floor and thence to the land masses (Longuet-Higgins and Ursell, 1948). Micro-seismograph networks of tripartite stations in the Caribbean and in the western Pacific Ocean regularly obtain fixes on hurricanes by intercepting these microsiesmic waves. However, the behavior of microseisms between storm centers and receiving stations has not been extensively studied, and it

is evident that such investigation should be useful in determining broad geological characteristics of the earth's crust beneath the ocean bottom without the need for conducting seismic surveys at sea.

Submarine geology is another field in which oceanographic research is being actively pursued. As Shepard (1948) indicates the work of the past ten years shows that the generally accepted theories of sedimentation and submarine geology require extensive revision. The present emphasis on the study of modern sediments along the Gulf Coast only emphasizes the obvious fact that a reef or a stratigraphic trap is basically an end-product of such oceanographic factors as supply of nutrients and sediments, wave action, tides, currents, and changes in sea level. However, the general practice is not to study these basic and limiting geophysical factors in their own right, but to study their biological and geological expression instead. In other words, present day emphasis is placed on studying the system, rather than the cause of the phenomena. Because of this unbalanced program of investigation, there is, for example, little or no knowledge of tidal conditions in the ancient embayments in the Gulf of Mexico, nor is there much information as to whether catastrophic storms such as hurricanes, with their storm tides and wave erosion, ever occurred during the Tertiary.

Even more startling is the lack of applied theory on how wave refraction and current patterns cause sedimentary and ecological conditions to vary in the neighborhood of ancient bioherms and strand lines, even though recent work by one of the authors in the atolls of the Marshall Islands and by Munk and Traylor (1947) on continental coast lines indicates that such a development is a distinct possibility. The speed with which such a poorly developed field of investigation can be exploited depends upon whether there is an economic necessity for the development of the forecasting aspects of paleo-oceanography. If such a day should come, the handful of geophysicists and geologists who received graduate training in meteorology and oceanography during World War II are logical candidates for developing this new phase of exploration geophysics which would be concerned with "hindcasting" the occurrence of ancient environmental conditions using techniques by which present environmental conditions can be forecasted. In other words, there is need for the development of geophysicists who can work in the field of paleo-oceanography by combining the skills of the geologist with those of the oceanographer and meteorologist.

CONCLUSIONS

The sciences of meteorology and oceanography are now developed to the point where they offer an objective, scientific approach to weather and oceanic problems. Reliance on qualitative, generalized weather or oceanic information for the solution of specific problems has been made obsolete by specialized meteorological and oceanographic techniques in keeping with the scientific specialization in other aspects of geophysical exploration. Though the scientific approach available through meteorology and oceanography usually permits only a reduction of

losses rather than their elimination, the same is true in most scientific and engineering applications, and the time is approaching when management will investigate critically losses attributed to the elements rather than accepting them automatically as "Acts of God." The experience of the geophysicist during the past two decades in reducing the percentage of dry holes can readily be extrapolated to the conclusion that the company which utilizes the best scientific information bearing on an operating problems will ultimately enjoy the most favorable competitive position. The exploration geophysicist, in other words, not only requires seismology, terrestrial magnetism, and gravimetry in his repertoire but also oceanography and meteorology in order to carry on petroleum exploration efficiently.

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SURVEY OF GEOPHYSICAL EDUCATION IN THE UNITED STATES AND CANADA IN 1948*

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At the annual meeting of the Society of Exploration Geophysicists in 1948 the Committee on Geophysical Education was constituted a standing committee and was commissioned to make an annual survey of the status of geophysical education in universities and colleges of the United States and Canada. A total of 426 questionnaires was sent to the responsible officials of these institutions and 325, or 76 per cent, responded. The majority of the responses was negative. No geophysics was being taught. A total of 150 institutions reported that they were teaching at least one course in some branch of geophysics. Forty institutions were teaching courses in petroleum exploration and 26 were teaching courses in mining exploration geophysics. The universities of British Columbia, Montreal, Saskatchewan and McGill University in Canada and Michigan College of Mining and Technology in the United States reported that they were interested primarily in mining exploration geophysics. A total of 306 students were enrolled in curricula or were undergraduate majors preparing for degrees in exploration geophysics.

A total of 34 bachelor's degrees in geophysics were given as follows: California Institute of Technology (2), University of California (5), Colorado School of Mines (13), Pennsylvania State College (2), Toronto (6), University of Tulsa (2) and Saint Louis University (4). A total of 26 master's degrees were conferred by the following institutions: California Institute of Technology (6), University of California in Berkeley (1), Colorado School of Mines (1), Columbia University (3), University of Michigan (3), Pennsylvania State College (1), University of Toronto (10) and Saint Louis University (1). Six doctors, degrees were given in Geophysics, one by California Institute of Technology, one by the University of California in Berkeley, two by Harvard University, one by Saint Louis University and one by the University of Toronto.

Those institutions which gave instruction in exploration geophysics seem to fall into three classes:—those institutions which offer one elementary course in applied geophysics, those which give a limited amount of advanced training, particularly to geologists and geological engineers, and those which have organized curricula leading to degrees in this field. According to the returns, the institutions

* Report of the Standing Committee on Geophysical Education of the Society of Exploration Geophysicists. The members of this committee are D. C. Skeels, M. King Hubbert, C. A. Heiland, Beno Gutenberg, Perry Byerly and Rev. J. B. Macelwane, Chairman. Manuscript received by the Editor December 2, 1949.

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which offer one elementary course in applied geophysics are Acadia University, University of Alabama, Baylor University, Brigham Young University, University of Colorado, Franklin and Marshall, University of Houston, University of Idaho, University of Kansas, Marietta College, Massachusetts Institute of Technology, Miami University, Millsaps College, Mississippi State College, Montana School of Mines, New Mexico School of Mines, University of Oklahoma, University of Pittsburgh, Rensselaer Polytechnic Institute, Rutgers University, South Dakota School of Mines and Technology, Texas Christian University, and University of West Virginia. In the second class are those institutions which give advanced courses in applied geophysics, either petroleum geophysics or mining geophysics or both, and largely to geologists and geological engineers, are the University of British Columbia, Cornell University, Colorado State College, Emory University, University of Georgia, Harvard University, Johns Hopkkins University, Lehigh University, Louisiana State University, McGill University, University of Michigan, Michigan College of Mining, University of North Carolina, Oregon State College, Queen's University, University of Saskatchewan, University of Southern California, Stanford University, University of Tennessee, Agricultural and Mechanical College of Texas, and Washington University of Saint Louis. Institutions of the third class are those enumerated under degrees, except the University of California in Los Angeles which offers majors in meteorology and oceanography, but from which no returns were received.

As will be seen from the table, there is a fairly large number of institutions that are giving courses in other phases of Geophysics than exploration for petroleum and other mineral deposits. In formulating our questionnaire, the Committee tried to choose such wording as would obviate misunderstanding and would leave no room for ambiguities; but in spite of this care, some institutions reported as courses in geophysics those parts of regular geological, physical, geographical and engineering courses which bear in some measure on the various fields of geophysics, at least in name. It is possible that we have not been able to make proper distinctions in transferring and interpreting some such replies for entry into the table.

In those institutions in which course sequences or curricula exist in the field of geophysics, the auspices under which students pursue these courses and the academic organization vary widely. There seem to be only five institutions which have organized a separate teaching department of geophysics as such. These are Colorado School of Mines, Pennsylvania State College, New Mexico School of Mines, the University of Utah, and Saint Louis University. And even at Pennsylvania State College the nomenclature is different. There are a number of research institutes of geophysics, such as that at University of California in Los Angeles and at the University of Alaska. There are several departments of Meteorology, such as that at New York University, at the University of California in Los Angeles, at Rutgers University and at the University of Chicago; and there is a division of meteorology at Pennsylvania State College. At some institu-

TABLE 1. NUMBER OF COURSES OFFERED*

Name of School	Petroleum Exploration	Mining Exploration	Applied Geophysics	Seismology	Geomagnetics	Geoelectricity	Atmospheric Electricity	Meteorology	Hydrology	Geodesy (Gravity)	Volcanology	Oceanography
Name of School												
University of Alabama	1E							1E	1E			
Acadia University			1E									
A. & M. College of Texas	2A											
University of Alberta		2A						1E	1E			
Amherst College		1E									1E	1E
Baylor University	1E											
Beloit College								1E				
British Columbia University		1A 1G										
Bucknell University								1E				
California Inst. of Tech.	1A 2G	1A 1G		1A 3G	1A	1A	1A	1A		2A 1G		1A
University of California (at Berkeley)	4A 1G			2A 3G	2A	2A	1A	1A	2A 1G	2A	1G	
University of Chicago								1E 1A 1G	1A 1G			1E 1A
Clark University								1E 1G				1G
Colgate University	1E							1E				
Colorado A. & M. College								1E				
University of Colorado	1E	1E										
Colorado School of Mines	1E 2A 2G	1E 2A 2G										
University of Connecticut								1E				
Cornell University	1E	1E 1A						1E				
University of Denver								1E				
Drexel Inst. of Tech.								1E				

* E—Elementary; A—Advanced; G—Graduate.

TABLE 1.—*Continued*

Name of School	Petroleum Exploration	Mining Exploration	Applied Geophysics	Seismology	Geomagnetics	Geoelectricity	Atmospheric Electricity	Meteorology	Hydrology	Geodesy (Gravity)	Volcanology	Oceanography
E. Tennessee State Col.								1E				
Emory University	1G	1G	1E					1E	1E			1E
College of Emporia								1E				
Fordham University				1E 1A			1E 1A	1E 1A				
Franklin & Marshall College	1E	1E		1E	1E	1E						
Georgia Inst. of Tech.								1E	1G			
University of Georgia	1A	1A	1A					2A 1G				
Harvard University	1A 1G			1E 1G				1G		1G		
University of Idaho	1E							1E				
Illinois Inst. of Tech.								1E				
University of Illinois	1G	1A										
Iowa State College	1E 1A			1E	1E	1E						
University of Houston			1A	1E	1E				1G	1E		1G
Kansas State College									1A			
Lehigh University				2E 1A	2E 1A					2E 1A		
Lewis College of Science and Technology								1E				
Louisiana State University	1A							1E 1A	10A 6G			
University of Maine								1E 1A	1E			
University of Michigan	1A	1A		?G				1E		?G		
Michigan College of Mining and Technology	1E	1E						1E				
University of Maryland								1E 1A 1G				
Massachusetts Institute of Technology	1E 1A	1E 1A			1E 1A	1E 1A				1A		1A

TABLE 1.—*Continued*

Name of School	Petroleum Exploration	Mining Exploration	Applied Geophysics	Seismology	Geomagnetics	Geoelectricity	Atmospheric Electricity	Meteorology	Hydrology	Geodesy (Gravity)	Volcanology	Oceanography
Miami University	1E	1E										
Michigan State College								1E	1E			
Milwaukee-Downer College								1E				
University of Montreal		1E										
College of Mt. St. Vincent								1E				
Mundelein College								1E				
University of New Hampshire								2E 1A				
New Mexico College A. & M.								1E	1E			
University of New Mexico							4A 1G	3A	3A			
University of North Carolina	1E 1A	1E 1A						1E 1A			1E	
Northwestern University								1E	1A			
Ohio University (Athens)								1E				
Ohio Wesleyan University								1E				
Oklahoma A. & M. College								1E 1A				
University of Oklahoma	1E				1E	1E						
Oregon State College	1A	1A		1G				3A	1A			
University of Oregon								1E				
Pennsylvania State College	1E 1A 1G	1E 1A			1A							
University of Pittsburgh	1E			1E				1E				
University of Puerto Rico								1E				
Queen's University	1A	1A										
Rensselaer Polytechnic Institute	1E											
Roosevelt College					1E	1E		1E				
Rutgers University		1E						3E 6G				

TABLE 1.—*Continued*

Name of School	Petroleum Exploration	Mining Exploration	Applied Geophysics	Seismology	Geomagnetics	Geoelectricity	Atmospheric Electricity	Meteorology	Hydrology	Geodesy (Gravity)	Volcanology	Oceanography
Saint Louis University	6A 3G	6A 3G		6A 7G	2A 3G	3G	1G	5E 8A 4G	2A 2G	2G		
College of St. Rose								1E				
St. Norbert College								1E				
College of St. Theresa								1E 1A				
St. Vincent College								1E				
San Diego State College								1E				
University of San Francisco				1E								
San Francisco State College								1E				1E
San Jose State College								1E 1A	1E		1E	
University of Saskatchewan		1A			1G	1G	1G	1E 1A		1G		
University of South Dokota								1E				
University of Southern California	1A	1A									1G	1G
State University of Iowa								1E	1E			
University of Tennessee								1E 1A				
Texas Christian University	1E											
Texas College of A. & S.				1A						1A		
University of Toledo								1E				
University of Toronto	1A 1G	1A 1G		1G								
Tulane University	1E 2A 2G											
University of Tulsa	1E 3A 1G			1A	1A					1A		
Vanderbilt University								1E				
Valparaiso University								1E				

TABLE 1.—*Continued*

Name of School	Petroleum Exploration	Mining Exploration	Applied Geophysics	Seismology	Geomagnetics	Geoelectricity	Atmospheric Electricity	Meteorology	Hydrology	Geodesy (Gravity)	Volcanology	Oceanography
Washburn Municipal University								1E				
Washington University	1A 1G	1A 1G		1A 1G	1A 1G	1A 1G		1A		1A 1G	1A 1G	
Wayne University	1G							2E 2A	1E			
Wellesley College								1E			1A	
Western Reserve University								1E				
Xavier University				1E 2A				1A				
Brigham Young University	1E							1E 1A 1G	1E			

tions the group of students working for degrees in geophysics is within the department of geology or of geological sciences, as is the case at the University of California (in Berkeley), at California Institute of Technology, at Columbia University and Harvard University. In other cases it is organized under the department of physics as at Fordham University, at Lehigh University, and at the University of Toronto. There are a few specialized graduate and research institutes in some of the other branches of geophysics especially in oceanography as at Scripps Institution of Oceanography at La Jolla, at Woods Hole and at the University of Washington. Other outstanding research institutions of this kind are the Department of Terrestial Magnetism and the Geophysical Laboratory of the Carnegie Institution of Washington in Washington, D. C. There may be and undoubtedly are others which were not covered by our survey.

The picture of geophysical education which is presented by the survey is that of a rapidly developing discipline subject to growing pains but otherwise healthy. There is an increasing consciousness of a content distinct from either physics or geology as ordinarily taught in colleges and universities. Under the circumstances the Committee continues to feel that any accrediting procedure on the part of the Committee would be premature if not a mistake.

REPORT OF RADIO FACILITIES COMMITTEE

Organization

Three independent, but closely cooperating organizations, are concerned with the matter of geophysical radio facilities. These are the Society of Exploration Geophysicists, through its Radio Facilities Committee; the American Petroleum Institute, through its Central Committee on Radio Facilities and its Sub-committee on Geophysical Use of Radio; and the National Petroleum Radio Frequency Coordinating Association and its regional frequency coordinating associations.

The S.E.G. Radio Facilities Committee was first appointed by President Cecil Green in 1947, and has been reappointed by each of his successors. This Committee consists of R. D. Wyckoff, Chairman, W. M. Rust Jr., Vice Chairman, R. Brewer, V. R. Kerr, J. P. Woods, D. Silverman, and B W. Sorge. This Committee, working through regional committees appointed by the officers of the S.E.G. Local Sections, has collected information concerning the radio facilities needs of the geophysical industry and through the API has presented them to the Federal Communication Commission at various allocation and rule making proceedings.

As a result of the vastly increased actual and proposed use of radio in industry, the FCC announced in 1947 an allocation hearing which resulted in the complete revision of the allocation of radio facilities and of the rules under which the various services operate. The Commission announced its intention of combining all the various branches of any industry using radio into a single service. Specifically, geophysics was combined with all other uses of radio by the petroleum industry into the new Petroleum Radio Service. This necessitated close cooperation between the geophysical users and other radio users in order to present a unified picture to the FCC. This was accomplished in a very successful manner by the cooperation between the SEG Radio Facilities Committee and the API Central Committee on Radio Facilities. The API has appointed Messrs. Wyckoff and Rust to the Central Committee of Radio Facilities and Wyckoff, Rust and Silverman to the Committee on Geophysical Use of Radio. These selections were made on the basis of recommendations from the S.E.G. Radio Facilities Committee. The API has retained Mr. Joseph E. Keller as counsel to handle its relations with the Federal Communication Commission.

When the FCC issued its new rules governing the Petroleum Radio Service, it included in paragraph 11.57 the following rule: "All applicants for, and licensees of, stations in these services shall cooperate in the selection and use of the frequencies assigned in order to minimize interference and thereby obtain the most effective use of the authorized facilities." Since the API was not strictly representative of all users in the Petroleum Radio Service, Regional and National Radio Frequency Coordinating Associations were organized to meet the requirements of this rule.

The National and Regional Petroleum Radio Frequency Coordinating Associations are advisory organizations, whose members are representatives of the users of radio in the petroleum industry, including geophysics. Each user may have one representative as a member of the regional association in which the user operates and one representative as a member of the national association. The officers of the associations are elected by the members so that the associations are truly representative of the users. The Executive Committee of the National Association consists of twelve members; seven of whom are the chairmen of the seven regional associations, and the other five of whom are selected by these seven members from the following divisions of the petroleum industry: Production, Geophysics, Oil and Products Pipe Line, Gas Pipe Lines, and Refining. In practice, the representative of the geophysical users is the chairman of the S.E.G. Radio Facilities Committee. The API has appointed all twelve members of the National Executive Committee to its Central Committee on Radio Facilities so that the activities of the API Committee will reflect the requirements of the actual users.

The Frequency Coordinating Associations and API have agreed that the detailed frequency coordinating problems within the petroleum industry and with other industries with which the petroleum industry shares radio frequencies will be handled by the Associations and that all presentations to the Federal Communication Commission concerning general policies and industry-wide allocations will be handled by the API's Central Committee on Radio Facilities.

Frequencies

The FCC has assigned the following frequencies to the Petroleum Radio Service:

Exclusive Basis

Mc	Mc	Mc	Mc
25.02	33.18	48.66	48.98
25.06	33.22	48.70	49.02
25.10	33.26	48.74	49.06
25.14	33.30	48.78	49.10
25.18	33.34	48.82	49.14
25.22	33.38	48.86	49.18
25.26	48.58	48.90	
25.30	48.62	48.94	

Shared Basis

Kc	Mc	Mc
1,602	30.66	153.17
1,628	30.70	153.23
1,652	30.74	153.29
1,676	30.78	153.35
1,700	30.82	158.31
2,292	153.05	158.37
4,637.5	153.11	158.43

Developmental Grant

Mc	Mc	Mc	Mc
456.05	456.55	457.05	457.55
456.15	456.65	457.15	457.65
456.25	456.75	457.25	457.75
456.35	456.85	457.35	457.85
456.45	456.95	457.45	457.95

2,450–2,500*
3,500–3,700*
6,425–6,575*
11,700–12,200*

* The exact frequency and the authorized bandwidth will be specified in the authorization.

The National Petroleum Radio Frequency Coordinating Association has agreed with the geophysical representatives that the frequencies 25.02, 25.06, 25.10, 25.14 and 25.18 mc shall be recommended exclusively to geophysical users and the frequencies 1,602, 1,628, 1,652, 1,676 and 1,700 kc shall be recommended exclusively to geophysical users insofar as Petroleum Radio Service is concerned. The frequencies 2,292 and 4,637.5 kc are available for geophysical use on an emergency basis. It was further agreed that the frequencies 25.22, 25.26, 25.30, 30.66, 30.70, 30.74, 30.78, 30.82, 153.05, 153.11, 153.17, 153.23, 153.29, 153.35, 158.31, 158.37 and 158.43 would be recommended for geophysical users on a "secondary sharing basis." By "secondary sharing basis" is meant that the geophysical user shall be fully responsible for the avoidance of harmful interference to other petroleum radio users licensed to operate on these frequencies.

It was agreed at the National Petroleum Radio Frequency Coordinating Association meeting in Kansas City, Missouri on June 13, 1949 that subject to further advice from the Radio Facilities Committee of the S.E.G., geophysical applicants in other than the 1,600 to 1,700 kc band would have a final stage input power limitation of 100 watts and in the 1,000 to 1,700 kc band, a limitation of 25 watts. Several geophysical users have pointed out that under special circumstances, higher powers are necessary. This will be a topic for discussion at the 1950 annual meeting of the SEG.

Procedure

In order to comply with paragraph 11.57 of the FCC Rules and Regulations, an applicant should obtain frequency recommendations from the Regional Petroleum Radio Coordinating Association

before filing his application for a license with the FCC. The seven regions and the names and addresses of the Regional Frequency Coordinating Committee chairmen are:

Region 1: Maine, Vermont, New Hampshire, New York, Rhode Island, Connecticutt, New Jersey, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, Massachusetts, District of Columbia.
Chairman: W. A. Shipman, United Fuel Gas Company
Box 1273, Charleston, Eest Virginia

Region 2: Wisconsin, Michigan, Illinois, Indiana, Ohio, Kentucky
Chairman: J. D. McCullough
Buckeye Pipe Line Company, Lima, Ohio

Region 3: Tennessee, North Carolina, South Carolina, Alabama, Georgia, Florida
Chairman: L. C. Bomar
Southern Natural Gas Company
Box 2563, Birmingham, Alabama

Region 4: Arkansas, Louisiana, Texas, Mississippi
Chairman: R. S. Caplan
Gulf Refining Company, Pipe Line Division
Box 2100, Houston, Texas

Region 5: North Dakota, South Dakota, Minnesota, Kansas, Nebraska, Iowa, Oklahoma, Missouri
Chairman: F. J. McElhatton
Panhandle Eastern Pipe Line Company
1221 Baltimore
Kansas City, Missouri

Region 6: Montana, Wyoming, Utah, Colorado, New Mexico
Chairman: Karl S. Hagius
Colorado Interstate Gas Company
Box 1087
Colorado Springs, Colorado

Region 7: Washington, Oregon, Idaho, Nevada, California, Arizona
Chairman: David Sheffert
Western Geophysical Company
1333 South Hope Street
Los Angeles 15, California

The letter to the Regional Association should give the following information:

The input power to the final stage; the number of units; the fact that they are mobile; the general area in which they will operate; the fact that they are for geophysical use; and the allocated frequencies on which the equipment is capable of operating. The Committee will recommend all of the allocated frequencies and the FCC in issuing a license will, as in the past, include on a single license all allocated frequencies. A copy of the letter of recommendation from the Regional Frequency Coordinating Association should be attached to the license application when filed with the FCC.

Radio Location Facilities

The FCC has under consideration at the present time the question of establishing Radiolocation Service as a regular service, rather than having it on an experimental basis as in the past. This service, if established, will not be part of the Petroleum Radio Service and frequency recommendations from the Petroleum Radio Frequency Coordinating Association will not be required. Definite action on the matter will probably be taken during 1950.

Revised Rules

The new FCC Rules and Regulations are somewhat more stringent than in the past. It is essential that geophysical users conform carefully to these Rules and Regulations in order to maintain our good standing with the Commission. Everyone should read FCC Rules and Regulations Part 11—"Rules Governing Industrial Radio Services," a copy of which can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. for ten cents.

R. D. WYCKOFF, *Chairman*
W. M. RUST, JR., *Vice Chairman*

PATENTS*

4—ACCELEROMETER

U. S. No. 2,484,165. C. M. Hathaway. Iss. 10/11/49. App. 4/5/45.

Accelerometer. A mechanical accelerometer having a weight suspended between two liquid-filled bellows and having a central tube with adjustable openings to each of the bellows so that damping may be adjusted.

12—ACOUSTIC MEASUREMENTS

U. S. No. 2,483,821. F. A. Firestone. Iss. 10/4/49. App. 6/28/45. Assign. Sperry Products, Inc.

Inspection of a Solid Part Utilizing Supersonic Transmission. A supersonic inspection system in which a plate to be inspected is placed between a transmitter and receiver and all immersed in castor oil which attenuates standing waves without interfering with transmitted waves.

U. S. No. 2,486,890. R. W. Stanmyre. Iss. 11/1/49. App. 5/25/46.

Decibeloscope. A signal-intensity indicator in which the signal is rectified and applied to a number of parallel voltage dividers adjusted so that various fractions are applied to thyratron tubes with indicator lamps.

U. S. No. 2,487,135. F. P. Herrnfeld. Iss. 11/8/49. App. 1/5/46. Assign. U. S. A.

Amplifier for Underwater Listening Apparatus. An underwater listening system having a magnetostriction hydrophone with preamplifier and an amplifier with selective band filters, the output being selectively applied to either headphones, loud speaker, electron-ray indicator or supersonic detector.

U. S. No. 2,490,452. W. P. Mason. Iss. 12/6/49. App. 8/16/46. Assign. Bell Telephone Laboratories, Inc.

Generation of Transverse Vibrations in Liquids. A cylindrical torsional vibrator made of crystalline ammonium dihydrogen phosphate for generating shear waves in a high-viscosity liquid.

U. S. No. 2,491,186. E. L. Kent. Iss. 12/13/49. App. 7/12/45. Assign. C. G. Conn, Ltd.

Apparatus for Analyzing Complex Waves. A system for analyzing a complex wave by driving in synchronism with the fundamental a light-shield having patterns corresponding to the harmonics and illuminating the patterns with a lamp energized by the wave, the transmitted light being picked up by a photocell whose output is analyzed by parallel filters connected to indicators.

U. S. No. 2,491,189. T. H. Long, Iss. 12/13/49. App. 6/16/45. Assign. C. G. Conn, Ltd.

Apparatus for Analyzing Waves. A system for analyzing a complex wave by driving in synchronism with the fundamental a light-shield having patterns corresponding to the harmonics and illuminating the patterns at two points displaced in phase, the transmitted light being picked up by two photocells whose outputs are analyzed by discriminators supplied with two quadrature register voltages and the discriminator outputs indicated.

U. S. No. 2,491,190. T. H. Long. Iss. 12/13/49. App. 6/30/45. Assign. C. G. Conn, Ltd.

Apparatus for Analyzing Waves. A system for analyzing a complex wave by driving in synchronism with the fundamental a light-shield having patterns corresponding to the harmonics and illuminating the patterns at two points displaced in phase, the transmitted light being picked up by two photocells whose outputs are fed to vector adders and indicated.

* Abstracts by O. F. Ritzmann, Gulf Oil Corporation.

U. S. No. 2,492,062. R. K. Potter. Iss. 12/20/49. App. 11/5/46. Assign. Bell Telephone Laboratories, Inc.

Device for Portrayal of Complex Waves. A system for recording the frequency-time pattern of speech waves by analyzing the microphone signal with a number of filters connected in parallel and whose outputs are scanned by a commutator, the filter output being used to actuate a printer bar against a synchronously-rotating spiral printing rotor.

16—AIRPLANE FLIGHT INSTRUMENTS

U. S. No. 2,484,730. L. K. Perry. Iss. 10/11/49. App. 8/21/45.

Universal Float Inclinometer. An aircraft inclinometer having a spherical chamber with a spherical inertia mass with a number of bearing projections and connected to an indicator by a system of levers.

U. S. No. 2,485,552. E. F. Aumuller. Iss. 10/25/49. App. 4/24/47. Assign. The Sperry Corp.

Gyroscopic Artificial Horizon. A horizon gyro mounted in a U-shaped gimbal ring and having a balanced horizon bar pivoted on the inner sides of the gimbal ring so that no gimbal-lock of the gyro can occur.

U. S. No. 2,486,402. A. Hacskaylo. Iss. 11/1/49. App. 9/13/46.

Automatic Control System. An automatic altitude control for aircraft having a barometric rate-of-climb detector which actuates contacts to control the elevator servo-motors.

U. S. No. 2,486,578. T. O. Summers, Jr. Iss. 11/1/49. App. 2/28/39 and 11/11/42.

Gyro Vertical. A gyro vertical having a rotor spinning in a case supplied with air and having openings through which the air may escape to set up precessing forces, the openings being obstructed by gravity-controlled valves with reactive surfaces which restrain movement of the valve.

U. S. No. 2,486,779. A. J. Fairbanks. Iss. 11/1/49. App. 11/22/43. Assign. U. S. A.

Stall Warning Indicator. An airplane stall-warning device having a vane extending from the leading edge of a wing in the region of the airstream separation point and actuating a microswitch connected to an indicator.

U. S. No. 2,487,809. G. W. Hoover and E. E. Easton. Iss. 11/15/49. App. 9/28/44.

Combined Attitude and Directional Instrument for Aircraft. A combined artificial horizon and compass having a gyro-held vertical transparent light-polarizing cylinder viewed horizontally through a polarizing window and arranged so that the compass indication on the outside of the cylinder and the horizon attitude on the inside of the cylinder may be seen simultaneously.

U. S. No. 2,489,218. R. J. Herbold. Iss. 11/22/49. App. 11/7/44. Assign. L. M. Hughes.

Instrument for Landing Aircraft. A landing aid for aircraft using a line of lights along the runway center line with shields to limit the beam to the proper angle of approach and a photocell on the plane indicating the direction to the lights.

U. S. No. 2,489,219. R. J. Herbold. Iss. 11/22/49. App. 12/28/44. Assign. L. M. Hughes.

Apparatus Including an Altimeter for Aiding the Landing of Aircraft. A landing aid for aircraft using a line of light along the runway and an oscillating photocell on the plane indicating the direction of the line.

U. S. No. 2,489,220. R. J. Herbold. Iss. 11/22/49. App. 3/15/45. Assign. L. M. Hughes.

Light-Sensitive Altitude and Direction Indicator. A landing aid for aircraft using a line of light along the runway and a photocell on the plane with shields arranged so that the area of photocell illumination will produce a course indication.

U. S. No. 2,489,221. R. J. Herbold. Iss. 11/22/49. App. 6/26/45. Assign. L. M. Hughes.

Craft Locating Apparatus. A photoelectric beacon-locating device having two photocells with oppositely-tapered cathodes so that light from the beacon passing through a shield will vary the two tube currents and actuate a direction indicator.

U. S. No. 2,489,222. R. J. Herbold. Iss. 11/22/49. App. 6/7/46. Assign. L. M. Hughes.

Electric Means for Indicating the Altitude and Position of a Craft When Landing on a Runway. A landing aid for aircraft using a line of light along the runway and a pair of photocells on each wing tip with shields so that the differential cell currents produce signals which are combined into an altitude indication.

U. S. No. 2,489,223. R. J. Herbold. Iss. 11/22/49. App. 6/25/46. Assign. L. M. Hughes.

Anticollision Apparatus. A photoelectric aircraft detector using two photocells with filters so that one is sensitive to infrared and the other to normal sky light and indicating changes in their differential currents.

U. S. No. 2,489,294. T. W. Kenyon. Iss. 11/29/49. App. 6/21/47. Assign. Kenyon Gyro & Electronics Corp.

Flight Attitude Indicating Instrument. A device having a gyro vertical connected by a system of geared shafts to a combined pitch and roll indicator.

U. S. No. 2,492,012. R. M. Smith. Iss. 12/20/49. App. 9/1/39. Assign. Radio Corp. of America.

Radio Frequency System for Altitude or Distance Measurement. A radio pulse-echo type of altimeter in which an r-f reference signal is mixed with the pulse signal and the frequency variation indicated as rate of climb.

U. S. No. 2,492,148. R. J. Herbold. Iss. 12/27/49. App. 5/13/47. Assign. L. M. Hughes.

Automatic Navigating Instrument for Craft-Guidance. An automatic craft-guidance device in which a photocell is maintained pointing at a star and coordinated with a gyro and a chronometer to plot the course on a map, and arranged to maintain the course along a predetermined one marked on the map by a template.

U. S. No. 2,492,371. L. J. Sivian. Iss. 12/27/49. App. 1/10/45. Assign. Bell Telephone Laboratories, Inc.

Apparatus for Measuring Air Velocity. An acoustic anemometer having an obstacle which produces noise in a wind and a microphone shielded from the wind to pick up the noise.

48—CASING PERFORATOR

U. S. No. 2,488,803. P. Charrin. Iss. 11/22/49. App. 5/31/46.

Gun Perforator. A casing perforating gun in which the charges are fired in sequence by an electric motor in the gun unit pulling a brush through a channel and contacting the cartridges in succession.

68—COMPUTING DEVICES

U. S. No. 2,486,068. M. E. Shishini and M. A. H. El-Said. Iss. 10/25/49. App. 7/19/44 and 6/19/46.

Electrical Device for Effecting the Multiplication or Division of Independent Quantities. An electronic wattmeter in which rectifiers are used to obtain logarithmic signals which are added and converted to anti-logarithm by a grid-controlled triode.

U. S. No. 2,488,909. R. J. Hardy. Iss. 11/22/49. App. 1/14/44 and 7/8/47. Assign. Société Française Radio Electrique.

System Indicating the Direction of Variation of an electric Quantity, and Applications. A device for indicating whether a varying electrical signal is increasing or decreasing by applying the signal to a condenser through a resistor whose terminals are connected to the grids of a double triode with balanced plate circuits and a differential indicator.

80—CORE BARREL

U. S. No. 2,490,512. C. L. Deely. Iss. 12/6/49. App. 3/12/46.

Core Barrel. A core barrel in which the top of the inner barrel is on ball bearings and the bottom end rides against a shoulder concentric with the drill when weight is applied but rides against an eccentric shoulder when lift is applied so as to break off the core, and with the core catcher in a tapered surface whose axis is at a slight angle to the axis of the drill.

84—CORE ORIENTATION

U. S. No. 2,489,566. C. T. Engle. Iss. 11/29/49. App. 11/27/45. Assign. Eastman Oil Well Survey Co.

Core Orienting Apparatus. A wire-line core barrel which cuts a groove in the side of the core and has a pendulum inclinometer which marks on a record disk the relative position of the groove and the low side of the hole.

92—DRILL

U. S. No. 2,485,098. T. Johnson. Iss. 10/18/49. App. 4/23/48.

Structure Drill. A coring drill using reverse fluid circulation and having an enlargement on the drill stem just above the bit with openings which permit the fluid to enter an annular channel and an inner upward channel which carried the core to the surface.

U. S. No. 2,485,826. P. J. Harinck. Iss. 10/25/49. App. 4/19/48.

Well Drilling Means. A drill which drills a normal hole and also has expanding cutters on the side so that the hole is enlarged sufficiently to permit following up the drill with casing.

104—EARTH AUGER

U. S. No. 2,491,908. J. E. Roberts and A. O. Roberts. Iss. 12/20/49. App. 8/11/45.

Earth Drilling Device. A shallow drill having a number of gear-driven earth augers arranged in a circle to cut interconnecting holes about a central core.

108—ECHO SOUNDING

U. S. No. 2,489,997. A. E. Anderson. Iss. 11/29/49. App. 3/6/40 and 9/8/43. Assign. Raytheon Manufacturing Co.

Range Indicator for Multirange Recorders. An echo-sounding recorder in which the paper speed is adjusted by changing the radius of a crank arm and the proper scale indicated by a lamp connected to the arm in use.

U. S. No. 2,490,595. E. Merten. Iss. 12/6/49. App. 6/16/47. Assign. Shell Development Co.

Hydrophone. A moving-coil electromagnetic hydrophone in which the coil is driven by a diaphragm and having inside the case an elastic tube whose interior is connected to the surrounding water so that immersion causes the tube to expand and compress the air in the apparatus to equalize pressure on both sides of the diaphragm.

U. S. No. 2,491,540. W. W. Wiseman and R. B. Wright. Iss. 12/20/49. App. 12/31/40.

Frequency Variation System for Echo Ranging. An echo ranging system in which changes in transmitter frequency will automatically effect a similar change in the tuning of a heterodyne receiver by obtaining both the transmitted frequency and the receiver intermediate frequency from the same oscillator through mixers.

124—ELECTRICAL PROSPECTING

U. S. No. 2,488,811. S. D. Eilenberger. Iss. 11/22/49. App. 9/20/43. Assign. Chicago Coin Machine Co.

Electronic Control Device. An electrical-conductivity testing device having two electrodes near the material being tested, one electrode being connected to the input and the other to the output of a high-gain unstable amplifier whose intensity of oscillation is indicated.

132—ELECTROMAGNETIC PROSPECTING

U. S. No. 2,483,417. E. A. Johnson. Iss. 10/4/49. App. 10/23/41.

Method and Apparatus for Detecting Permeable Bodies. A system for detecting magnetic bodies by a field coil excited with low-frequency a-c and two balanced pick-up coils connected in opposition to an indicator.

U. S. No. 2,489,920. P. C. Michel. Iss. 11/29/49/. App. 7/3/46. Assign. General Electric Co.

Metal Detector. A device for detecting metal particles in non-metallic material having a pair of primary coils excited by an oscillator and a pair of balanced secondary coils connected in series opposition to a phase-shift detector.

136—EXPLOSIVE

U. S. No. 2,491,692. E. J. Shimek. Iss. 12/20/49. App. 11/8/45.

Borehole Explosive Charge. An internally-threaded sleeve for connecting a dynamite cartridge to the end of a loading pole and having inner and outer scorings so that the pole may be unscrewed one turn and pressure will collapse the sleeve outwardly to form an umbrella in the hole and keep the dynamite from being pulled up when the pole is withdrawn.

U. S. No. 2,492,459. J. E. Bondurant. Iss. 12/27/49. App. 11/3/44. Assign. Phillips Petroleum Co.

Blasting Cap Circuit Tester. An electric cap-circuit tester having three terminals, a battery and resistor being connected between two terminals and a milliammeter between one of these and the third terminal so that the tester may be calibrated and both shunt and series tests made.

140—FLAW DETECTOR

U. S. No. 2,483,821. F. A. Firestone. Iss. 10/4/49. App. 6/28/45. Assign. Sperry Products, Inc.

Inspection of a Solid Part Utilizing Supersonic Transmission. A supersonic inspection system in which a plate to be inspected is placed between a transmitter and receiver and all immersed in castor oil which attenuates standing waves without interfering with transmitted waves.

U. S. No. 2,486,984. R. G. Rowe. Iss. 11/1/49. App. 5/7/43. Assign. The Carborundum Co.

Vibration Apparatus for Testing Articles. A testing device which sets up vibrations in flat specimens by mounting them at nodal points, vibrating them by contact with the stylus of an electromechanical vibrator excited from a variable-frequency oscillator, picking up the vibrations as sound and comparing with the exciting signal.

U. S. No. 2,488,811. S. D. Eilenberger. Iss. 11/22/49. App. 9/20/43. Assign. Chicago Coin Machine Co.

Electronic Control Device. An electrical-conductivity testing device having two electrodes near the material being tested, one electrode being connected to the input and the other to the output of a high-gain unstable amplifier whose intensity of oscillation is indicated.

U. S. No. 2,489,860. B. Carlin. Iss. 11/29/49. App. 11/14/45. Assign. Sperry Products, Inc.

Apparatus for Inspecting Materials by Wave Trains. A supersonic flaw detector which is made sensitive to flaws lying close to the surface by cutting off the receiver at the instant the transmitted pulse ends and turning it on a predetermined time later.

148—FLOW METER

U. S. No. 2,483,965. A. Chaumerliac. Iss. 10/4/49. App. 12/31/41 and 3/30/45. Assign. Ernest Gauthier.

Indicator of Fluid Flow. A flow meter having a cylindrical case with a transparent end and an oblique-hole in the wall which directs the fluid against a spring-biased vane whose deflection is observed.

U. S. No. 2,487,083. H. D. Warshaw. Iss. 11/8/49. App. 5/16/45.

Fluid Flow Responsive Transmitter for Telemetering Systems. A flowmeter having an orifice which is deflected against a spring, the orifice being carried on a magnetic armature in a pair of coils wound around the flow tube and connected to a differential impedance indicator.

U. S. No. 2,490,792. K. Fischer. Iss. 12/13/49. App. 5/15/44. Assign. Fischer & Porter Co.

Flowmeter. A rotameter type flow-meter having internal beads on the float tube and whose metering float has a number of inverted cups which create turbulence thereby making the indication independent of viscosity.

U. S. No. 2,491,445. J. J. Cunningham, R. W. B. Johnston and R. E. Phillips. Iss. 12/13/49. App. 2/24/47. Assign. Shell Development Co.

Flowmeter. A device for measuring the flow of charged air-blown pulverized materials by measuring the electric charge collected on an insulated electrode or section of pipe.

U. S. No. 2,491,998. S. J. Mikina. Iss. 12/20/49. App. 2/19/44. Assign. Westinghouse Electric Corp.

Fluid-Flow Indicator. A flow meter in which the differential pressure across an orifice actuates bellows whose force is balanced by an electromagnet and the current measured.

U. S. No. 2,492,371. L. J. Sivian. Iss. 12/27/49. App. 1/10/45. Assign. Bell Telephone Laboratories, Inc.

Apparatus for Measuring Air Velocity. An acoustic anemometer having an obstacle which produces noise in a wind and a microphone shielded from the wind to pick up the noise.

U. S. No. 2,492,493. W. H. Misson. Iss. 12/27/49. App. 9/18/44. Assign. one-half to Frank V. Mayo.

Generator and Fluid Flow Meter. An electrostatic generator which indicates the flow rate or the nature of non-conducting material flowing in a pipe line and having a pair of screens across the pipe, one screen being coated with insulating material and connected to the pipe and the other screen being bare and connected to the grid of an amplifier.

168—GAS ANALYSIS

U. S. No. 2,483,829. W. D. Hershberger. Iss. 10/4/49. App. 5/28/45. Assign. Radio Corp of America.

Microwave Acoustic Gas Analysis Method and System. A gas analysis method in which the gas flows through a cavity resonator excited by modulated microwaves of frequency near an absorption band and the resulting acoustic pressure variations picked up by a microphone and fed back to the microwave modulator.

U. S. No. 2,484,207. H. E. Criner and R. A. Baudry. Iss. 10/11/49. App. 2/16/45. Assign. Westinghouse Electric Corp.

Gas Density Meter. A gas density indicating device having a blower which produces a gas pressure proportional to density, the pressure being measured by a spring bellows connected to a reluctance-type transducing element.

U. S. No. 2,487,077. G. M. Shepherd. Iss. 11/8/49. App. 12/28/43. Assign. U. S. A.

Colorimetric Gas Detection. A carbon monoxide indicator having silica gel impregnated with palladium sulfate, sulfuric acid and ammonium molybdate which changes color from clear yellow to blue on exposure to carbon monoxide.

U. S. No. 2,488,812. L. S. Galstaun and D. D. Thomas. Iss. 11/22/49. App. 4/10/45.

Gas Analysis Apparatus. An automatic Orsat apparatus having two electrically-operated valves which connect the mercury reservoir to vacuum and to atmosphere and are controlled by electric contacts so as to automatically reverse the flow of gas.

U. S. No. 2,489,180. J. T. Hayward. Iss. 11/22/49. App. 4/1/39.

Method of Detecting Gas in Well Drilling Fluids. A system for detecting and measuring combustible gas in drilling mud by separating the gas, adding a volume of air controlled by the amount of separated gas so as to maintain constant volume and analyzing the gas-air mixture by combustion.

U. S. No. 2,489,893. C. Johnson. Iss. 11/29/49. App. 1/16/40. and 8/4/44. Assign. Bailey Meter Co.

Apparatus for Purifying and Feeding Sample Gas. A gas-sampling apparatus in which the sample is aspirated, washed and separated from the aspirating liquid.

172—GEOCHEMICAL PROSPECTING

U. S. No. 2,490,642. L. B. Lipson. Iss. 12/6/49. App. 11/7/45. Assign. The Geotronics Corp.

Method and Apparatus for Physicochemical Analysis. A method of soil analysis in which samples are ground and dried, irradiated with ultra-violet light, and the fluorescence radiation measured with a Geiger-Muller tube, and then the ultra-violet source disconnected and the inherent radioactivity of the sample measured.

180—GRAVIMETER

U. S. No. 2,490,628. S. G. Isserstedt. Iss. 12/6/49. App. 9/23/42. Assign. Minneapolis-Honeywell Regulator Co.

Motor-Driven Leveling Support. An automatically-leveled gimbal support for an aerial camera in which pairs of mercury switches control reversible motors geared to the gimbals.

U. S. No. 2,492,244. P. F. Shivers. Iss. 12/27/49. App. 9/24/42. Assign. Minneapolis-Honeywell Regulator Co.

Leveling Support. An automatic leveling support for an aerial camera in which leveling servomotors are automatically controlled by pendulums and the azimuth motor is remotely controlled by the pilot to correct for drift.

188—HYGROMETER

U. S. No. 2,489,455. O. J. Leone. Iss. 11/29/49. App. 12/11/44. Assign. The Bristol Co.

Determination and Control of Moisture Content in Gaseous Media. A method of humidity control by bringing a sample of gas to constant pressure and constant dry-bulb temperature and controlling the moisture content in response to the wet-bulb temperature.

192—INCLINOMETER

U. S. No. 2,486,529. G. Jackson. Iss. 11/1/49. App. 1/22/45. Assign. Eastman Oil Well Survey Co.

Inclination Indicating Apparatus. A pendulum-type inclinometer in which the pendulum has a vertical pointer which is held away from the record by fluid pressure and raised against a record disc by a spring when pressure is released by stopping circulation.

U. S. No. 2,490,785. A. S. De Vany. Iss. 12/13/49. App. 1/8/48.

Liquid Contact Tilt Indicating Switch. An electrically-indicating inclinometer in which a fine stream of mercury falls on to a mosaic of insulated electrodes separately connected to indicators whose circuit is completed by the stream of mercury.

196—INFRARED MEASUREMENTS

U. S. No. 2,483,746. J. U. White. Iss. 10/4/49. App. 7/19/46. Assign. The Perkin-Elmer Corp.

Optical Apparatus Utilizing Light of a Wave Length Above a Selected Value. An infrared spectrometer for gas analysis in which short wave lengths are eliminated by diffracting them with an echelette grating whose effective grating space is the same as the longest wave length to be used.

200—LEVEL INDICATOR

U. S. No. 2,483,532. R. C. de Palacio. Iss. 10/4/49. App. 3/1/44 and 2/19/45.

Automatic Level Gauge for Liquids Contained in Tanks. A remotely-indicating tank gauge having liquid-filled tubes leading from the top and the bottom of the tank to the two arms of a mercury U-tube, the tube to the top of the tank also being connected to the center of the U-tube.

U. S. No. 2,483,914. A. L. Lawson. Iss. 10/4/49. App. 9/4/45. Assign. Cardox Corp.

U-Tube Pressure Gauge. A gauge for indicating level of CO_2 in a tank and having a sight gauge with a splash pot at each end of the sight tube connected to the tank through a porous plug to reduce surges.

U. S. No. 2,483,967. T. R. Eberwine. Iss. 10/4/49. App. 4/22/47.

Tapping Tube and Liquid Level Indicator. A tank or barrel-tapping tube with insulated metal sections outside the tube connected to terminals at the top so that conductivity of the liquid from the tube to the sections closes circuits to indicating lamps.

U. S. No. 2,484,690. C. A. de Giers. Iss. 10/11/49. App. 7/24/47. Assign. The Liquidometer Corp.

Electric Liquid Level Indicating Device. A fluid level indicator for a tank having a resistor with a series of reed-like magnetic contact fingers along its length and a floating magnet which draws the contact against the resistor.

U. S. No. 2,486,207. M. K. Richards. Iss. 10/25/49. App. 8/11/45. Assign. U. S. A.

Liquid Level Measuring Apparatus. A system for measuring liquid level in a tank in which gas is bubbled from a tube at the bottom of the tank and the difference in the gas pressure between the bubble tube and the top of the tank indicated by a manometer.

U. S. No. 2,486,930. C. A. de Giers and R. A. F. Sandberg. Iss. 11/1/49. App. 12/29/45. Assign. The Liquidometer Corp.

Liquid Level Gauge with Tilt Correction. A float-type liquid level gauge having three floats on separate arms 120° apart connected by linkages to a triangular plate which connects to the indicating rod through a gimbal joint.

U. S. No. 2,488,758. B. L. Binford. Iss. 11/22/49. App. 1/26/46. Assign. Magnetrol, Inc.

Magnetic Control Device. A liquid level control for a non-ferrous tank having an iron float and a magnet on the outside of the tank actuating a switch.

U. S. No. 2,490,627. A. H. Hofberg. Iss. 12/6/49. App. 6/30/45. Assign. Radio Corp. of America.

Photoelectric Liquid Level Indicator. A device for indicating the level of a transparent liquid in a sight tube by using a narrow light beam falling on a photo tube, the light beam being interrupted by the meniscus.

216—MAGNETIC COMPASS

U. S. No. 2,487,044. W. C. Cude. Iss. 11/8/49. App. 10/1/45.

Compass. A hand compass with luminous dial and an aluminum case with copper cup to provide eddy-current damping and with sound-cushioning material under the pivot mounting and over the jewel cup to eliminate noise.

224—MAGNETIC RECORDER

U. S. No. 2,483,398. W. A. Brastad and L. F. Borchardt. Iss. 10/4/49. App. 3/3/45. Assign. General Mills, Inc.

Recording Process Utilizing the Magnetic Field of a Current Conducted by the Record Member. A magnetic recording system in which the recording current flows through the record wire between two closely-spaced electrodes over which it passes.

U. S. No. 2,483,729. L. B. Greenleaf. Iss. 10/4/49. App. 12/1/44. Assign. C. G. Conn, Ltd.

Magnetic Recording Apparatus. A magnetic recorder reel having a spring cover band which engages the reel flanges, the band having external sockets which are engaged by fingers on the recorder to move the band away from the reel when in use.

U. S. No. 2,484,097. E. Keller and F. Roggen. Iss. 10/11/49. App. 10/21/44 and 3/20/45.

Magnetic Transducer with Wear-Resistant Guide Surfaces. A magnetic recording head having a grooved hard stone wire-guiding member with a transverse groove which carries the magnetic core.

U. S. No. 2,484,552. M. Camras. Iss. 10/11/49. App. 7/17/44. Assign. Armour Research Foundation of Illinois Institute of Technology.

Magazine for Magnetic Recording and Reproducing Devices. An easily-replaceable magnetic-recorder magazine containing two reels, a recorder head, and a level wind arrangement, and having shafts on the reels for engaging the drive.

U. S. No. 2,484,568. H. A. Howell. Iss. 10/11/49. App. 10/18/46. Assign. Indiana Steel Products Co.

Magnetic Recorder Method and Means. A magnetic recorder in which base boost is attained by using a paper tape coated on one side with magnetizable material and having two recording-reproducing heads one of which is on the magnetic side of the tape and the other on the paper side.

U. S. No. 2,485,451. W. P. Lear. Iss. 10/18/49. App. 10/30/45. Assign. Lear, Inc.

Magnetic Recorder Unit. A magnetic-recorder cabinet with removable chassis members for the magazine drive and the electronic components.

U. S. No. 2,485,539. S. I. Weiss. Iss. 10/18/49. App. 6/6/45.

Magnetic Sound Recorder Utilizing Varying Cathode Currents. A magnetic recording system in

which the microphone output is applied to two tubes in class B push-pull operation with recording coils in each of their cathode circuits

U. S. No. 2,487,170. H. Nygaard. Iss. 11/8/49. App. 4/16/47. Assign. Frederick Hart & Co., Inc.

Magazine Type Magnetic Recorder. A magnetic recorder unit having a driving chassis and a magazine with supply and take-up reels which engage shafts on the chassis driven from a flywheel through shiftable friction wheels.

U. S. No. 2,488,277. C. J. Falk, R. K. Fairley and T. T. Short. Iss. 11/15/49. App. 6/15/48. Assign. General Electric Co.

Magnetic Wire Footage Meter. A magnetic wire footage counter having an electromagnetic marking head and an electromagnetic pickup head a fixed distance apart and arranged that the marking head is excited when a mark passes the pickup head and the pulses also counted, the gain of the pickup amplifier being controlled by the repetition rate of the pulses so as to correct for amplitude variations caused by changes in speed of the wire.

U. S. No. 2,488,717. S. D. Eilerberger. Iss. 11/22/49. App. 11/19/45. Assign. Chicago Coin Machine Co.

Magnetizable Wire Recording System and Method. A magnetic recorder in which the wire is transversely magnetized by passing it obliquely between two transversely located pole pieces.

U. S. No. 2,490,053. G. O. Harm. Iss. 12/6/49. App. 8/22/44. Assign. The Brush Development Co.

Level-Wind Mechanism for Magnetic Recorders. A magnetic recorder having a guide over which the record wire passes from one reel to the other and a double screw for oscillating the guide so as to wind the wire evenly.

U. S. No. 2,490,771. S. J. Begun. Iss. 12/13/49. App. 9/6/45. Assign. Magnetone, Inc.

Magnetic Recording and Reproducing Apparatus Using an Endless Spirally-Wound Magnetic Tape. An endless magnetic tape recorder having a magazine which rides on a phonograph turntable and has a guide disc to keep the spiral convolutions free and a separate magnetic reproducing head mounted on the phonograph board.

228—MAGNETIC TESTING

U. S. No. 2,483,471. E. R. Mann, S. W. Stanton and T. T. Goldsmith, Jr. Iss. 10/4/49. App. 1/24/45. Assign. Allen B. DuMont Laboratories, Inc.

Process and Apparatus for Examining Materials. A magnetic testing apparatus in which the specimen is magnetized by a coil excited from a saw-tooth oscillator and the pickup amplifier gated by a signal from the oscillator, the flux density in the specimen also being automatically controlled by a feed-back connection.

U. S. No. 2,489,066. R. C. Ø. Wiig. Iss. 11/22/49. App. 9/29/41 and 10/3/45.

Determination of the Content of a Mineral in Ores and the Like. A device for detecting ferro-magnetic material having two opposed d-c excited coils with the sample in one coil and a magnetic yoke between the coils with a spring-biased magnetic indicator across the yoke.

232—MAGNETOMETER

U. S. No. 2,485,847. O. H. Schmitt. Iss. 10/25/49. App. 9/23/44. Assign. U. S. A.

Combination Magnetometer and Gradiometer. A magnetic direction indicator for aircraft having two flux-valve cores mounted on each wing tip and inter-connected so that signals proportional to the sum and to the difference of the field component at the wing tips may be observed.

U. S. No. 2,485,931. T. Slonczewski. Iss. 10/25/49. App. 4/20/43. Assign. Bell Telephone Laboratories, Inc.

Magnetic Field Strength Indicator. A magnetometer having three mutually-perpendicular flux valves whose outputs are squared and added by means of thermocouples or parabolic rectifiers.

U. S. No. 2,487,047. F. C. Farnham. Iss. 11/8/49. App. 11/12/47.

Elastic Suspension and Resilient Mounting Means for Magnetic Systems. A magnetic balance having a needle passing horizontally through a hub which is suspended by horizontal torsion filaments and with resilient arms which clamp the ends of the hub.

U. S. No. 2,488,341. T. Slonczewski. Iss. 11/15/49. App. 9/25/45. Assign. Bell Telephone Laboratories, Inc.

Detection System. An aircraft magnetometer having three mutually-perpendicular second-harmonic flux-valves two of which are used to control the orientation of the system and their outputs also passed through a squaring rectifier and added to the output of the detector element to compensate for misalignment.

U. S. No. 2,488,389. E. P. Felch, Jr., F. G. Merrill and T. Slonczewski. Iss. 11/15/49. App. 9/25/45. Assign. Bell Telephone Laboratories, Inc.

Detection System. An aircraft magnetometer having three mutually-perpendicular second-harmonic flux-valves two of which are used to control orientation of the system and their outputs also passed through a squaring rectifier and combined with battery current passed through the detector element to compensate part of the ambient field and also misalignment.

U. S. No. 2,490,102. J. H. Stein. Iss. 12/6/49. App. 5/10/46.

Magnetic Field Angular Gradientometer. A device for indicating the angle between a magnetic component measured at two points and having a flux-valve at each point automatically oriented to zero response by a servo-motor, the motors also driving indicators on a common dial so that the angle between them can be observed.

U. S. No. 2,491,736. E. M. Irwin. Iss. 12/20/49. App. 4/18/46.

Magnetic Pickup Device and Method of Balancing the Device. A method of balancing the output and relative configuration of the two flux-valves of a gradiometer by rotating them into various relative positions and adjusting the output of one.

U. S. No. 2,492,182. G. F. Robinson. Iss. 12/27/49. App. 4/12/46. Assign. Federal Telephone and Radio Corp.

Approach Alarm System. An automobile counting or alarm system having an open-cored solenoid buried in the ground and connected with a tuning condenser to the grid of a gas tube so that the approach of ferromagnetic material produces a phase shift and makes the tube conducting which actuates an alarm.

236—MASS SPECTROMETRY

U. S. No. 2,486,452. H. W. Washburn and C. E. Berry. Iss. 11/1/49. App. 4/30/45. Assign. Consolidated Engineering Corp.

Mass Spectrometry. A mass spectrometer ion source in which the insulator between the collimating electrodes is shielded from the ion path by conducting baffles spaced from each other and connected to the electrodes so as to eliminate the effect of static charges on the insulator.

U. S. No. 2,489,344. H. W. Washburn. Iss. 11/29/49. App. 7/16/45. Assign. Consolidated Engineering Corp.

Mass Spectrometry. A mass spectrometer having a suppressor electrode in the electron beam to suppress secondary emission from scattered electrons.

U. S. No. 2,490,278. A. O. C. Nier. Iss. 12/6/49. App. 10/31/47. Assign. Regents of the University of Minnesota.

Mass Spectrometer Tube Ion Source Assembly. A unitary ion source assembly with a flange which may be bolted to a flange on the spectrometer tube.

252—MUD LOGGING

U. S. No. 2,489,180. J. T. Hayward. Iss. 11/22/49. App. 4/1/39.

Method of Detecting Gas in Well Drilling Fluids. A system for detecting and measuring combustible gas in drilling mud by separating the gas, adding a volume of air controlled by the amount of separated gas so as to maintain constant volume and analyzing the gas-air mixture by combustion.

272—ORIENTATING DRILLING TOOLS

U. S. No. 2, 489,788. A. Knudsen. Iss. 11/29/49. App. 8/12/46.

Orienting Device. A photographically-recording orienting device having two balls which roll in annular races, one ball being magnetic and attracted to a magnet in the device and the other being non-magnetic and indicating the low side of the hole.

U. S. No. 2,492,794. R. W. Goble and G. Jackson. Iss. 12/27/49. App. 8/28/44. Assign. Eastman Oil Well Survey Co.

Methods of and Apparatus for Transmitting Intelligence to the Surface from Well Bores. A system for transmitting to the surface a signal indicating the orientation of a whipstock by attaching to the whipstock a radio transmitter controlled by a rolling ball switch or compass switch and coupling the transmitter to the drill pipe.

276—PERMEABILITY TESTING

U. S. No. 2,484,507. K. L. Hertel. Iss. 10/11/49. App. 4/3/44. Assign. University of Tennessee Research Corp.

Controlling Fluid Flow Through Restricted Conduits. A device for obtaining a known ratio of flow resistance between two annular constricted passageways by adjusting the position of a piston which carries the inlet tube.

288—PRESSURE GAUGE

U. S. No. 2,483,635. C. R. A. Grant. Iss. 10/4/49. App. 7/16/45 and 10/3/46.

Pressure Gauge. A Bourdon gauge having the free end of the Bourdon tube connected to a crank pin on the pointer spindle by a flexible steel strip.

U. S. No. 2,485,515. G. P. Sutton, C. M. Wolfe and J. A. Widenmann. Iss. 10/18/49. App. 10/3/47. Assign. Aerojet Engineering Corp.

Pressure Pickup. A condenser-type pressure pickup having a diaphragm and a closely-spaced insulated condenser plate which is connected to an auxiliary parallel condenser and a coil to a coaxial cable lead.

U. S. No. 2,486,135. L. M. Ellison. Iss. 10/25/49. App. 10/3/45. Assign. Ellison Draft Gage Co., Inc.

Pressure Gauge Having a Combined Inclined and Vertical Tube. A mercury pressure gauge having a vertical tube with an inclined tube at the top to magnify variations and having adjustable scales along the tubes arranged so that the vertical scale is moved an amount equal to the vertical component of the adjustment on the inclined scale.

U. S. No. 2,486,146. C. Frondel. Iss. 10/25/49. App. 10/1/48. Assign. Cambridge Thermionic Corp.

Pressure Responsive Transducer. A piezoelectric pressure gauge having pairs of tourmaline crystals supported by the inner electrodes with the entire unit embedded in a core of wax and hermetically sealed by a sheath of neoprene.

U. S. No. 2,486,587. J. T. Callahan, Jr., D. O. Kocmich and P. F. Adair. Iss. 11/1/49. App. 8/16/44.

Pressure Measuring Apparatus. A pressure-measuring device having a bellows attached to a pivoted arm with electric contacts in indicator or follow-up circuits and with the arm balanced by an elastic member controlled from a measuring screw.

U. S. No. 2,486,976. W. R. Perret. Iss. 11/1/49. App. 8/15/46. Assign. U. S. A.

Pressure Measuring Device. A vacuum gauge using a Philip's oscillation-type gauge connected to a frequency meter for measuring the high frequency a-c component of the gauge.

U. S. No. 2,489,123. P. S. Dickey. Iss. 11/22/49. App. 6/18/45. Assign. Bailey Meter Co.

Pressure Responsive Mechanism for Pressure Measuring Apparatus. A bellows-type pressure gauge having a limit stop which engages the stem of a relief valve so as to open it and avoid damage from excessive pressures.

U. S. No. 2,490,468. R. G. Picard. Iss. 12/6/49. App. 10/19/46. Assign. Radio Corp. of America.

Vacuum Gauge Structure. A Philip's gauge having a flattened metal envelope which is coated with caesium and serves as cathode with a magnetic field across the flat faces and a wire anode in the space between them.

304—RADIOACTIVITY LOGGING

U. S. No. 2,484,422. M. Muskat and N. D. Coggeshall. Iss. 10/11/49. App. 1/11/45. Assign. Gulf Research & Development Co.

Method of Detecting Mud Films on Exposed Rock Strata. A method of locating drilling mud on the wall of a hole by adding sufficient radioactive tracer to the mud before drilling so that mud film will produce a higher radioactivity log indication than the formations.

U. S. No. 2,487,058. S. Krasnow and L. F. Curtiss. Iss. 11/8/49. App. 10/24/39 and 3/28/44. Assign. S. Krasnow.

Measuring System for Borehole Radioactivity. A method of radioactivity logging in which the detector is lowered through and radioactivity detected inside the drill stem.

U. S. No. 2,488,491. R. F. Davis. Iss. 11/15/49. App. 7/19/46. Assign. Well Surveys, Inc.

Well Logging Null Recorder. A well-log recording system in which the measured quantity is obtained as a voltage applied to a resistor and balanced by a current supplied from the surface and automatically adjusted by a servo-motor in the well apparatus.

308—RADIOACTIVITY MEASUREMENTS

U. S. No. 2,483,991. E. O. Wollan, L. A. Pardue and N. Goldstein. Iss. 10/4/49. App. 3/3/45. Assign. U. S. A.

Radiation Exposure Meter. A photographic x-ray and gamma-ray exposure meter having a piece of x-ray film with a filter of metallic cadmium or metallic silver from 1 to 2 millimeters thick.

U. S. No. 2,484,493. R. E. Fearon. Iss. 10/11/49. App. 6/29/48. Assign. Well Surveys, Inc.

Method and Apparatus for Measuring Hardness and Intensity of Penetrating Radiation. A radiation measuring device having a sealed system in which an ionizable gas is circulated through concentric detectors between which there is an absorbing material and measuring the difference between detector currents.

U. S. No. 2,485,469. J. S. Allen and B. B. Rossi. Iss. 10/18/49. App. 11/6/46. Assign. U. S. A.

Method and Means for Detecting Ionization. A radioactivity detector having an atmosphere of 80% argon and 20% carbon dioxide and in which the electric field is below that for which electron multiplication takes place.

U. S. No. 2,485,516. R. W. Thompson. Iss. 10/18/49. App. 7/10/45. Assign. U. S. A.

Shallow Plane Proportional Counter. A proportional counter having an argon and carbon-dioxide atmosphere and a pair of flat parallel cathodes with anode wires between them.

U. S. No. 2,485,586. L. Goldstein. Iss. 10/25/49. App. 2/1/47. Assign. International Standard Electric Co.

Geiger Counter. A radiation detector using a Geiger-Muller counter tube with a transparent window at one end and a phototube for indicating the photon emission of the counter.

U. S. No. 2,486,845. G. Herzog. Iss. 11/1/49. App. 11/21/45. Assign. The Texas Co.

Measurement of Wall Thickness. A method of measuring wall thickness by the absorption of penetrating radiation with a source on one side of the wall and using two detectors on the other side of the wall, one of which covers a large wall area and the other a small area so that accurate alignment with the source may be made.

U. S. No. 2,486,902. A. Wolf. Iss. 11/1/49. App. 1/8/46. Assign. The Texas Co.

Measurement of Thickness. A device for measuring the wall thickness of pipe without access to inside the pipe and having a bracket which holds a radiation source so that the radiation passes through the pipe to a detector and the intensity indicated.

U. S. No. 2,486,944. D. G. C. Hare. Iss. 11/1/49. App. 3/14/46. Assign. The Texas Co.

Radiation Detector. A gamma-ray detector having a bundle of metal cathode tubes with transverse perforated plates in the tubes and anode wires extending axially down the tubes and passing through a central hole in the plates.

U. S. No. 2,486,946. G. Herzog. Iss. 11/1/49. App. 8/26/44. Assign. The Texas Co.

Measurement of Penetrative Radiation. A circuit for converting the pulses of a radiation detector to an audible sound by converting the pulses to a d-c voltage which is applied to bias the grid of a tube to which is also applied an audio tone and the output connected to earphones.

U. S. No. 2,487,216. M. Blau and I. Feuer. Iss. 11/8/49. App. 2/27/47. Assign. Canadian Radium & Uranium Corp.

Apparatus and Method for Measuring Movement of a Body. A system for detecting motion of a balance beam by attaching to the beam a radioactive material which moves close to two ionization chambers having a common electrode whose potential variation is indicated.

U. S. No. 2,487,797. H. Friedman, W. A. Zisman and M. V. Sullivan. Iss. 11/15/49. App. 12/10/46

Detection of Water in Fuels. A device for detecting water in a fuel line and having a beta-ray source mounted inside the line with a radiation-permeable window in the pipe and a Geiger-Muller counter outside, changes in intensity of transmitted radiation being used to detect contamination.

U. S. No. 2,488,269. C. W. Clapp. Iss. 11/15/49. App. 6/19/48. Assign. General Electric Co.

Noncontacting Thickness Gauge. A thickness gauge using a source of penetrating particles on one side of the material and an ionization chamber on the other with the beam modulated by a rotating shutter and variations in the a-c component of the transmitted beam indicated.

U. S. No. 2,489,133. G. Herzog. Iss. 11/22/49. App. 11/10/44. Assign. The Texas Co.

Radiation Detecting Device. A radiation detector having a number of parallel plate cathodes with holes through which extend anode wires each of which is connected to a separate amplifier and the amplifier outputs connected together.

U. S. No. 2,489,436. W. W. Salisbury. Iss. 11/29/49. App. 12/17/47. Assign. Collins Radio Co.

Method and Apparatus for Producing Neutrons. A device for producing neutrons by evaporating deuterium through a palladium tube and bombarding with deuterium ions.

U. S. No. 2,489,627. F. E. Dudley. Iss. 11/29/49. App. 6/9/48.

Radiation Counter Tube. A gas-filled counter tube having a glass envelope with a central wire anode and a cylindrical cathode whose inner surface has longitudinal corrugations to produce an irregular field distribution in the tube.

U. S. No. 2,490,298. A. Ghiorso and C. M. Gordon. Iss. 12/6/49. App. 5/13/49. Assign. U. S. A.

Radiation Detecting Apparatus. Apparatus for measuring the radioactivity of successive samples which are introduced through an air lock and placed on a turntable which moves them into a gas-filled detecting chamber.

U. S. No. 2,490,642. L. B. Lipson. Iss. 12/6/49. App. 11/7/45. Assign. The Geotronics Corp.

Method and Apparatus for Physicochemical Analysis. A method of soil analysis in which samples are ground and dried, irradiated with ultra-violet light and the fluorescence radiation measured with a Geiger-Muller tube, and then the ultra-violet source disconnected and the inherent radioactivity of the sample measured.

U. S. No. 2,491,220. E. G. Segré and C. E. Wiegand. Iss. 12/13/49. App. 9/4/45. Assign. U. S. A.

Neutron Detector. A device for detecting neutrons in the presence of gamma rays having two concentric cylinders with the sample in the inner one, boron trifluoride in the space between the cylinders and paraffin surrounding the outer one, the inner cylinder being at a positive potential with respect to the outer one and the ionization current measured.

U. S. No. 2,491,320. P. G. Koontz. Iss. 12/13/49. App. 7/27/44. Assign. U. S. A.

Neutron Detector and Method of Making Same. A device which is made radioactive by exposure to neutrons and having a thin metal backing sheet on which is pressed a layer of powdered manganese dioxide with a plastic binder.

U. S. No. 2,491,904. M. J. Poole. Iss. 12/20/49. App. 6/25/48.

Electronic Detection System. A radioactivity-detecting system having a target which may be bombarded and its charge integrated and an adjacent detector for measuring secondary emission, the detector counter being triggered by a predetermined charge on the target.

312—RADIO NAVIGATION

U. S. No. 2,483,557. W. J. O'Brien. Iss. 10/4/49. App. 8/27/45. Assign. The Decca Record Co., Ltd.

Radio Beacon System. A phase-comparison type radio navigation system in which the receiver is supplied with standard local signals whose phase relation is known in order to standardize the receiver indication.

U. S. No. 2,483,558. W. J. O'Brien. Iss. 10/4/49. App. 8/27/45. Assign. The Decca Record Co., Ltd.

Area Identification System. A radio navigation system in which three spaced transmitters radiate signals of different but related frequencies having a fixed multiple phase relationship and the frequencies of the signals from two of the transmitters are periodically interchanged.

U. S. No. 2,484,819. T. M. Ferrill, Jr. Iss. 10/18/49. App. 10/29/46. Assign. The Sperry Corp.

Radio Navigation System. A radio navigation apparatus for a mobile craft in which the direction-finding loop is stabilized with a gyroscope which is caused to process in response to integrated changes in the radio bearing so as to compensate for lateral drift of the craft.

U. S. No. 2,484,862. E. C. Streeter, Jr. Iss. 10/18/49. App. 2/18/48. Assign. The Sperry Corp.

Compass Stabilized Direction Finder. A radio direction finder whose indicator is also connected to a compass so as to show absolute bearing.

U. S. No. 2,485,365. F. de Fremery. Iss. 10/18/49. App. 3/6/44 and 2/11/47. Assign. Hartford National Bank and Trust Co.

Method of Direction Finding by Means of Rotating Radio Beacons. A rotating-beam radio beacon in which the radiation pattern has a minimum and also has a frequency shift at a fixed point in the rotation and a return shift at another fixed point.

U. S. No. 2,488,022. W. A. Miller. Iss. 11/15/49. App. 2/1/45. Assign. Radio Corp. of America.

Radio Receiving and Indicating System. A glide-path aircraft-landing system using a scanning antenna and a synchronously-controlled c-r beam producing a symmetrical pattern whose center indicates the correct glide path.

U. S. No. 2,490,050. P. G. Hansel. Iss. 12/6/49. App. 11/7/45.

Navigation System. A radio navigation system using a dipole antenna revolving on the end of an arm and radiating a modulated carrier whose amplitude modulation and phase modulation are compared.

316—RADIO RANGING

U. S. No. 2,483,399. G. S. Burroughs. Iss. 10/4/49. App. 4/9/46. Assign. Federal Telecommunication Laboratories, Inc.

Radio Direction Finder. A radio direction finder having two right angle loops and an omnidirectional antenna, the loop signals being fed to quadrature coils of a goniometer whose pick-up coil is rotated by a motor which also drives an a-c generator on the same shaft, the phase of the goniometer signal being compared with the phase of the generator on a c-r tube screen.

U. S. No. 2,484,034. E. J. Isbister. Iss. 10/11/49. App. 4/24/45. Assign. The Sperry Corp.

Interval Measuring System. An arrangement for gearing a low-frequency phase shifter and a high-frequency phase shifter to a counter-type interval indicator by having the adjustments geared to the respective counter wheels through differential gears.

U. S. No. 2,484,651. H. F. Rost, K. H. Thunell, S. D. Vigren and P. H. E. Claesson. Iss. 10/11/49. App. 1/10/41 and 5/11/45.

Radio Direction Finder. An automatically tracking radar in which the field is scanned by a transmitter and reflector focussed on a detector with a rotating aperatured shield between the reflector and the detector, the shield being on the same shaft with contactors to detect variations in signal and control orienting motors.

U. S. No. 2,484,824. P. G. Hansel. Iss. 10/18/49. App. 9/12/45.

Radio Direction Finding Method and Apparatus. A radio direction finder in which the effective spacing of the antennas may be changed by multiplying the phase difference of the signals with a frequency multiplier in each antenna circuit.

U. S. No. 2,485,353. H. B. R. Boosman and C. J. de L. de la Sablonière. Iss. 10/18/49. App. 8/10/40 and 5/1/46. Assign. Hartford National Bank and Trust Co.

Radio Direction Finder. A radio direction finder having two mutually-perpendicular loops with independent amplifying channels and connected to quadrature plates of a c-r tube, the system having a switch for connecting the loops in parallel and an amplitude and phase-correcting network in one of the channels.

U. S. No. 2,485,578. C. W. Earp and J. D. Weston. Iss. 10/25/49. App. 2/3/44 and 3/22/45. Assign. International Standard Electric Corp.

Automatic Radio Direction Finding System. An electronic switch for switching antenna signals in a radio direction finder, the tube grids being grounded and the switching voltage applied to the cathodes and the output obtained from the plates.

U. S. No. 2,487,995. S. M. Tucker. Iss. 11/15/49. App. 5/26/41.

Pulse Echo Receiver with Regenerative Feedback. A radar receiver having regenerative feedback applied through a multi-section filter to provide delay in order to amplify recurrent signals and discriminate against random noise.

U. S. No. 2,489,075. N. Bishop. Iss. 11/22/49. App. 4/17/43. Assign. General Electric Co.

Pulse Echo Testing Apparatus. A device for testing radar equipment and having a parabolic radiator and axially-adjustable parabolic reflector mounted on a base and with the radar transmitter connected to the radiator through a transmission line and reverberation observed.

U. S. No. 2,491,542. J. R. Woodyard, E. L. Ginzton and V. R. Learned. Iss. 12/20/49. App. 9/7/43. Assign. The Sperry Corp.

Object Detector and Velocity Indicator. A radio continuous wave type Doppler effect velocity indicator in which sub-audible and supersonic beat frequencies are made audible by beating with local oscillators of known frequency.

U. S. No. 2,492,120. J. P. Smith. Iss. 12/20/49. App. 4/23/45. Assign. Radio Corp. of America.

Radio Direction and Ranging System. A radar system using a facsimile recorder and in which the receiver gating pulse is shifted in time synchronously with the rotation of the scanning drum in the recorder.

324—RECORDER

U. S. No. 2,485,839. D. L. O'Dea. Iss. 10/25/49. App. 4/29/48. Assign. Radio Corp. of America.

Magnetic-Photographic Rerecording System. A system for making a photographic record from a magnetic record using a circular magnetic core with two diametrically-opposed air gaps, the magnetic record being run past one air gap to excite the core and with a thin sheet of glass in the other gap which is stressed by the magnetic forces so that polarized light passing through the glass is modulated.

U. S. No. 2,486,661 & 2. R. G. Leitner. Iss. 11/1/49. App. 9/30/42. Assign. Frank Rieber.

Phonograph with Moving Stylus and Stationary Record. A phonograph recorder holding the record stationary in an inverted position and having a stylus which is driven in a spiral path at constant linear speed by a cone drive adjusted with the spiral follower.

332—SEA SAMPLER

U. S. No. 2,488,486. J. L. Worzel. Iss. 11/15/49. App. 4/11/46. Assign. U. S. A.

Bottom Sampler. A sea-bottom sampler having an open sampling tube at the front, a weighted middle portion and a finned tail, with the hitch line attached at the front end of the weighted section.

344—SEISMOGRAPH AMPLIFIER

U. S. No. 2,487,599. R. E. Schell. Iss. 11/8/49. App. 4/30/49. Assign. Radio Corp. of America.

Microphonism Testing Apparatus. A system for testing a vacuum tube for microphonics by subjecting it to a mechanical jar, amplifying its response and passing it through a delayed trigger circuit, and indicating the output a selected time after the jar.

368—SEISMOGRAPH TIMING

U. S. No. 2,489,400. A. G. Cooley. Iss. 11/29/49. App. 10/23/46. Assign. Times Facsimile Corp.

Tuning Fork. A temperature-compensated tuning fork made of two similar-shaped forks of different metals which are welded together at the base of the heel and at the tips of the tines.

U. S. No. 2,490,461. R. U. McKinney. Iss. 12/6/49. App. 4/12/46. Assign. Seismograph Service Corp.

Apparatus for Seismic Prospecting. A system for starting seismogram timing lines coincidentally with the shot moment by having the firing circuit completed by a relay which is closed at each revolution of the timing motor.

372—SEISMOGRAPH VOLUME CONTROL

U. S. No. 2,484,662. G. N. Wetzel. Iss. 10/11/49. App. 1/24/46. Assign. Collins Radio Co.

Automatic Acoustic Control for Public Address Systems and the Like. An automatic control for the volume of a public-address system operating in the presence of noise from electric-power-driven machinery in which a current transformer in the power mains actuates a marginal relay to cut out an attenuator in the speaker circuit when the machine load increases.

U. S. No. 2,489,126. C. H. Fay and T. J. Tvedt. Iss. 11/22/49. App. 1/27/48. Assign. Shell Development Co.

Automatic Volume Control for Seismograph Systems. An avc circuit for seismograph amplifiers having a control circuit with a primary delay and a separate circuit to provide rapid recovery.

376—SEISMOMETER

U. S. No. 2,483,770. A. B. Hildebrandt. Iss. 10/4/49. App. 12/22/45. Assign. Standard Oil Development Co.

Apparatus for Seismic Prospecting. A borehole seismometer having a spring-actuated clamp which engages the wall of the hole, the clamp being actuated by energizing a solenoid from a battery at the surface.

U. S. No. 2,487,029. R. G. Piety. Iss. 11/1/49. App. 3/7/45. Assign. Phillips Petroleum Co.

Geophone. An electromagnetic seismograph detector having two opposing annular magnetic circuits with a common air gap in which is mounted a moving coil wound on a mica cylinder.

U. S. No. 2,490,595. E. Merten. Iss. 12/6/49. App. 6/16/47. Assign. Shell Development Co.

Hydrophone. A moving-coil electromagnetic hydrophone in which the coil is driven by a diaphragm and having inside the case an elastic tube whose interior is connected to the surrounding water so that immersion causes the tube to expand and compress the air in the apparatus to equalize pressure on both sides of the diaphragm.

388—SHOT MOMENT RECORDING

U. S. No. 2,490,461. R. U. McKinney. Iss. 12/6/49. App. 4/12/46. Assign. Seismograph Service Corp.

Apparatus for Seismic Prospecting. A system for starting seismogram timing lines coincidentally with the shot moment by having the firing circuit completed by a relay which is closed at each revolution of the timing motor.

428—STRAIN GAUGE

U. S. No. 2,484,164. C. M. Hathaway. Iss. 10/11/49. App. 7/21/43.

Electromagnetic Strain Gauge. A variable air gap reluctance bridge type strain gauge in which the armature is moved by one of the knife edges through a lever arm and the bridge excited by an a-c source which also supplies a-c to a discriminator rectifier connected to the output of the bridge.

U. S. No. 2,485,735. L. K. Hyde. Iss. 10/25/49. App. 11/17/45. Assign. The Baldwin Locomotive Works.

Deflectometer. A mechanical extensometer having a counterbalanced follower which acts on an inclined surface to produce amplification.

U. S. No. 2,485,977. R. M. Mains. Iss. 10/25/49. App. 3/11/46. Assign. U.S.A.

Stress Measuring Device. A device for measuring forces on test models in a wind tunnel in which the model is suspended on a rod having filament-type strain gauges on it and protected by a streamlined tube.

U. S. No. 2,486,625. A. Allen. Iss. 11/1/49. App. 6/13/45. Assign. The Foxboro Co.

Electric Strain Measuring Device. A peak-measuring strain gauge having a dead soft lead strip with its ends cemented to the test piece and a filament-type strain gauge mounted on the lead strip so that elongation of the lead may be measured after the test.

U. S. No. 2,487,523. C. F. Coake. Iss. 11/8/49. App. 2/16/45. Assign. Senn Corp.

Electric Microgauge System. An electric gauge having an armature moving between two coils which are in tuned-grid circuits of two tubes operating as coupled oscillators and their differential plate currents indicated.

U. S. No. 2,487,681. A. Weisselberg. Iss. 11/8/49. App. 10/18/45.

Electrical Gauging Device. A gauging device having a tapered cantilever arm whose end is deflected and which has four filament-type electric strain gauges mounted on its sides.

U. S. No. 2,491,240. A. W. Zmuda and L. F. Hope. Iss. 12/13/49. App. 6/23/45. Assign. General Motors Corp.

Photoelectric Torsiograph. A device for detecting torsional vibrations in which the shaft carries two slotted discs one of which is fastened to the shaft and the other is carried by an inertia wheel and the variation of light passing through the superimposed discs measured.

U. S. No. 2,491,251. G. I. Chinn. Iss. 12/13/49. App. 7/3/47.

Torsion Dynamometer. A torsion gauge in which the torque is carried through a split ring, compressed air being supplied through an axial passage to a nozzle on one side of the split and impinging on a target on the other side and the air pressure drop indicated.

436—SUBMARINE SIGNALING

U. S. No. 2,484,036. J. R. Kauke. Iss. 10/11/49. App. 4/16/45.

Magnetostriction Hydrophone. A non-directional hydrophone having a thin nickel tube inside of which there is a central transverse wound core with a longitudinal magnet between each side of the core and the end of the tube.

U. S. No. 2,484, 626. A. C. Keller. Iss. 10/11/49. App. 7/26/46. Assign. Bell Telephone Laboratories, Inc.

Electromechanical Transducer. A multi-unit piezoelectric hydrophone in which the crystals have different resonant frequencies and are connected in reverse so that adjacent crystals are in phase at a frequency midway between their resonance frequencies.

440—SURFACE TESTING

U. S. No. 2,483,668. R. E. Reason and D. R. Berridge. Iss. 10/4/49. App. 3/24/43 and 6/12/44. Assign. Taylor, Taylor & Hobson Ltd.

Apparatus for Measuring or Indicating Roughness or Undulations of a Surface. A surface-testing apparatus in which the stylus and pick-up head are carried on a traversing member which is connected to the casing by a pair of straight-line linkages so that the traversing member moves in a reference plane.

U. S. No. 2,489,092. C. V. Larrick. Iss. 11/22/49. App. 9/25/46. Assign. General Electric Co.

High-Frequency Surface Testing Instrument. A device for measuring the electrical resistance of the surface layer of a material and having a microwave guide with a shorting plug at one end and means for holding the material against the other end, and an exciting line and detector entering the side of the wave guide.

U. S. No. 2,491,016. R. E. Reason. Iss. 12/13/49. App. 8/17/43 and 8/10/45. Assign. Taylor, Taylor & Hobson Ltd.

Apparatus for Measuring or Indicating the Roughness or Undulations of a Surface. A surface-testing apparatus in which the stylus and pick-up head are carried on a supporting member connected to the case by radius links so that the stylus moves in a circular path.

444—SURVEYING APPARATUS

U. S. No. 2,490,899. P. Cohen. Iss. 12/13/49. App. 6/17/46. Assign. United Shoe Machinery Corp.

Apparatus for Determining the Phase Relation of Sinusoidal Electric Signals. A system for detecting the phase difference between a sinusoidally-modulated transmitted light beam and its reflection by using the signals to trigger the sweep circuits of a c-r tube.

448—TENSION INDICATOR

U. S. No. 2,490,773. E. A. Black. Iss. 12/13/49. App. 11/13/45.

Tensiometer. A tensiometer which is inserted in a cable and having a pivoted beam on one end of the cable and two arms from the beam to the other end of the cable, one arm being replaceable by a calibrated spring.

456—THERMAL PROSPECTING

U. S. No. 2,484,736. J. Razek. Iss. 10/11/49. App. 5/19/45. Assign. O. W. Storey.

Apparatus for Determining Thermal Conductivity. A thermal conductivity apparatus using a slab of sample in contact with a slab of standard material and pairs of resistance elements at the outer surfaces and at the common surface, the voltage across resistances being measured so as to obtain a direct reading of conductivity.

U. S. No. 2,491,192. E. J. Martin and G. G. Scott. Iss. 12/13/49. App. 11/11/44. Assign. General Motors Corp.

Sealed Heat Ray Detector. An infra-red detector having a rock-salt window protected by a thin rubber diaphragm and an oscillating concave reflector which is periodically focussed on a thermopile.

460—THERMOMETER

U. S. No. 2,487,946. J. A. Senn. Iss. 11/15/49. App. 6/14/45.

Thermal Responsive Device and Mounting Therefor. A thermal element having a bell-shaped casing with a bimetallic diaphragm across the open end and containing a liquid which expands through a pressure-transmitting tube connected at the neck.

U. S. No. 2,487,968. F. R. Higley. Iss. 11/15/49. App. 6/29/44. Assign. Affiliated Gas Equipment, Inc.

Thermally Responsive Unit. A thermostatic element for lateral deflection and having a pair of longitudinally-bent strips with slightly concave adjacent surfaces to prevent buckling.

U. S. No. 2,490,933. E. L. Tornquist and W. S. Guyot. Iss. 12/13/49. App. 7/19/43.

Temperature Indicator. A color-changing temperature indicator having a solid dye-solvent which melts at a predetermined temperature and dissolves a dye and stains an absorbent material.

468—TIME INTERVAL METER

U. S. No. 2,483,556. W. J. O'Brien. Iss. 10/4/49. App. 8/27/45. Assign. The Decca Record Co., Ltd.

Frequency Divider Circuits. A frequency divider having a tuned output circuit fed by a tuned regulator circuit which is conductive only when a peak of the output coincides with a peak of the input signal.

484—TRANSDUCER

U. S. No. 2,484,030. C. E. Hastings and H. H. Ricker, Jr. Iss. 10/11/49. App. 8/12/46.

Electrical Deflectometer. A device for measuring deflections by moving a contact on a slide wire connected in a Wheatstone bridge circuit.

U. S. No. 2,484,626. A. C. Keller. Iss. 10/11/49. App. 7/26/46. Assign. Bell Telephone Laboratories, Inc.

Electromechanical Transducer. A multi-unit piezoelectric hydrophone in which the crystals have different resonant frequencies and are connected in reverse so that adjacent crystals are in phase at a frequency midway between their resonance frequencies.

U. S. No. 2,484,960. S. R. Rich. Iss. 10/18/49. App. 3/8/46. Assign. Tobe Deutschmann.

Phonograph Pickup Unit. A phonograph pickup having a stylus extending transversly from a magnetostrictive wire which is mounted in torsion between the poles of a permanent magnet with a pickup coil around one end of the wire.

U. S. No. 2,485,405. B. Olney, F. H. Slaymaker and W. F. Meeker. Iss. 10/18/49. App. 4/21/44. Assign. Stromberg-Carlson Co.

Dipole Microphone. A telephone operator's headset having two tubes from the mouth piece to a pressure-gradient microphone in the same case with receiver.

U. S. No. 2,485,432. L. B. Cornwell. Iss. 10/18/49. App. 11/28/45.

Magnetic Phonograph Pickup. A variable air gap magnetic phonograph pickup whose armature is resiliently suspended so that when the pickup head rests on the record the armature will be in register with the pole pieces.

U. S. No. 2,485,722. W. S. Erwin. Iss. 10/25/49. App. 1/31/45. Assign. General Motors Corp.

Crystal. A piezoelectric crystal for imparting mechanical vibration to a load and having tapered width and thickness so as to suppress the formation of resonant vibrations.

U. S. No. 2,486,099. B. B. Bauer. Iss. 10/25/49. App. 3/14/46. Assign. Shure Brothers, Inc.

Phonograph Pickup Having Fulcrum Suspended Drive Arm. A phonograph pickup in which the stylus mounting rotates freely in unstressed flexible bushings and is supported by a short vertical arm of elastic material.

U. S. No. 2,486,146. C. Frondel. Iss. 10/25/49. App. 10/1/48. Assign. Cambridge Thermionic Corp.

Pressure Responsive Transducer. A piezoelectric pressure gauge having pairs of tourmaline crystals supported by the inner electrodes with the entire unit embedded in a core of wax and hermetically sealed by a sheath of neoprene.

U. S. No. 2,486,150. C. K. Gravley. Iss. 10/25/49. App. 12/31/47. Assign. The Brush Development Co.

Piezoelectric Transducer and Method for Producing the Same. A hermetically-sealed piezoelectric crystal unit in which the unit is coated with nonconducting material containing reinforcing threads and covered with conducting particles over which a metal covering is electroplated.

U. S. No. 2,486,560. R. B. Gray. Iss. 11/1/49. App. 9/20/46. Assign. Erie Resistor Corp.

Transducer and Method of Making the Same. A phonograph pickup in which motion of the stylus stresses a condenser whose dielectric is barium titanate in the tetragonal crystalline state.

U. S. No. 2,487,216. M. Blau and I. Feuer. Iss. 11/8/49. App. 2/27/47. Assign. Canadian Radium & Uranium Corp.

Apparatus and Method for Measuring Movement of a Body. A system for detecting motion of a balance beam by attaching to the beam a radioactive material which moves close to two ionization chambers having a common electrode whose potential variation is indicated.

U. S. No. 2,487,523. C. F. Coake. Iss. 11/8/49. App. 2/16/45. Assign. Senn Corp.

Electric Microgauge System. An electric gauge having an armature moving between two coils which are in tuned-grid circuits of two tubes operating as coupled oscillators and their differential plate currents indicated.

U. S. No. 2,487,815. N. E. Lee. Iss. 11/15/49. App. 5/13/44.

Magnetostrictive Rod Unit. A magnetostrictive vibrator having a longitudinally-vibrating rod whose resonance may be adjusted by varying a magnetic air gap at its ends or by electrically varying the degree of magnetization.

U. S. No. 2,487,962. J. P. Arndt, Jr. Iss. 11/15/49. App. 8/29/47. Assign. The Brush Development Co.

Electromechanical Transducer. A piezoelectric microphone or loud speaker using a barium titanate disc with a conical two-dimensional bow across its face, the apex of the cone being mechanically coupled to a diaphragm.

U. S. No. 2,488,504. R. J. Rockwell. Iss. 11/15/49. App. 6/25/49.

Electromagnetic Pickup Unit. An electromagnetic phonograph pickup in which the stylus vibrates a single-turn coil in a magnetic field and also a small magnetic vane in a fixed coil, the former reproducing vertically-cut records and the latter laterally-cut records.

U. S. No. 2,488,586. G. Diemer. Iss. 11/22/49. App. 9/5/45 and 11/22/46. Assign. Hartford National Bank and Trust Co.

Piezoelectrical Apparatus. A piezoelectric vibrator in which the two masses are mechanically connected by crystals oriented so as to have their electrodes parallel to the axis of vibration.

U. S. No. 2,488,927. J. H. Owens. Iss. 11/22/49. App. 3/10/45. Assign. Radio Corp. of America.

Variable Bridge Transducer and Its Combination with a Radio Receiver. A phonograph pickup in which the stylus moves the middle plate of a push-pull condenser connected in an impedance bridge circuit in the pickup head fed by a remote oscillator and with the unbalance of the bridge detected with a coil connected to a remote detector.

U. S. No. 2,488,936. W. V. B. Roberts. Iss. 11/22/49. App. 12/12/40. Assign. Radio Corp. of America.

Frequency-Modulation Recording and Reproducing and its Combination with a Radio Receiver. A phonograph recorder in which the stylus is driven at constant amplitude at about 50 kc and frequency modulated.

U. S. No. 2,489,378 & 9. H. P. Kalmus. Iss. 11/29/49. App. 3/31/45 and 4/13/46. Assign. Zenith Radio Corp.

Modulated-Oscillator Type Phonograph Reproducing System. A phonograph pickup in which the stylus vibrates a metal plate near a coil in an oscillating circuit to produce an amplitude-modulated signal by changes in its "Q" quality factor.

U. S. No. 2,490,236. H. B. Shaper. Iss. 12/6/49. App. 6/17/47. Assign. The Brush Development Co.

Piezoelectric Transducer. A piezoelectric hydrostatic hydrophone using a series of lithium sulfate monohydrate crystals immersed in castor oil in a rubber housing.

U. S. No. 2,490,273. C. H. Kean. Iss. 12/6/49. App. 11/18/47. Assign. Standard Oil Development Co.

Structure for Magnetostriction Transducers. A magnetostrictive vibrator having a longitudinally-vibrating tube with a pair of wound core units inside the tube symmetrically supported on two sides of a transverse non-magnetic plate which also supports the tube.

U. S. No. 2,491,390. H. F. Olson. Iss. 12/13/49. App. 10/31/46. Assign. Radio Corp of America.

Electronic Transducer. A phonograph pickup or microphone in which a tapered anode of a vacuum tube is moved by an arm passing through a flexible diaphragm in the tube envelope.

U. S. No. 2,491 391. G. M. Rose, Jr. Iss. 12/13/49. App. 12/14/46. Assign. Radio Corp. of America.

Electronic Transducer. A transducer in which the anode of a vacuum tube is in the form of a tapered rod passing through a flexible diaphragm in the tube envelope to the vibrating medium and the cathode has a shield to focus the electrons on the rod.

U. S. No. 2,491,794. W. S. Bachman. Iss. 12/20/49. App. 11/28/44. Assign. General Electric Co.

Variable Resistance Phonograph Pickup. A phonograph pickup in which the stylus vibrates the midpoint of a strain-sensitive filament having at each end a mass in a viscous mounting and kept taut by springs.

U. S. No. 2,492,186. M. F. Royston. Iss. 12/27/49. App. 7/23/46. Assign. American Type Founders, Inc.

Reproducer for Hill and Dale and Lateral Cut Phonograph Recorders. A phonograph pickup having a coil which is oscillated vertically by hill-and-dale records and rotated by laterally-cut records, and with a pair of field magnets one of which may be reversed to provide the proper flux when changing the type of record.

U. S. No. 2,492,255. J. O. Angehrn. Iss. 12/27/49. App. 12/26/44.

Sealed-Coil Type Vibratory Magnet Loudspeaker. A loudspeaker having a small permanent magnet fastened to the diaphragm and vibrating in the air gap of a laminated shell-type field structure wound with an internal voice coil.

U. S. No. 2,492,429. R. S. John. Iss. 12/27/49. App. 8/17/45. Assign. Pfanstiehl Chemical Co.

Electric Translating Device. A phonograph pickup or displacement transducer made of a strip of polystyrene which is coated with a suspension of graphite in carbon tetrachloride, dried and then coated with lacquer.

U. S. No. 2,492,446. A. Schumann. Iss. 12/27/49. App. 5/16/44 and 9/15/45.

Piezoelectric Phonograph Pickup Having Resilient Coupling Member. A piezoelectric phonograph pickup having a Rochelle salt twister element connected to the stylus through a rubber sleeve.

496—VISCOSIMETER

U. S. No. 2,484,761. C. R. Stock. Iss. 10/11/49. App. 4/5/45. Assign. American Cyanamid Co.

Viscosimeter. A rotating-cup viscosimeter in which the drag on the inner cylinder is measured by means of an electrical resistance strain gauge bonded to an elastic supporting bar.

U. S. No. 2,485,424. P. B. Weisz. Iss. 10/18/49. App. 7/2/47. Assign. Socony-Vacuum Oil Co., Inc.

Viscosimeter. A direct-reading rotating-disc viscosimeter in which the disc is driven by a Selsyn motor which is controlled from a Selsyn transmitter driven by a synchronous motor, the drag of the disc being read on a meter in the Selsyn circuit.

U. S. No. 2,491,639. W. G. Bechtel and C. C. Kesler. Iss. 12/20/49. App. 1/9/48. Assign. Corn Industries Research Foundation.

Viscometer. A device for measuring the viscosity of thixotropic liquids having a container in which the material is constantly stirred and the torque required to drive a constant-speed impeller measured.

500—VOLTMETER

U. S. No. 2,490,579. D. H. Clewell. Iss. 12/6/49. App. 7/12/46. Assign. Socony-Vacuum Oil Co., Inc.

Direct-Current Measuring System. A voltmeter for measuring electrolytic potentials in which the potential is applied through a resistor to one plate of a continuously-varying capacity which is in the input circuit of a high-gain inverse-feedback amplifier whose output is connected to a balancing resistor between the other condenser plate and ground.

516—WELL SIGNALING

U. S. No. 2,492,794. R. W. Goble and G. Jackson. Iss. 12/27/49. App. 8/28/44. Assign. Eastman Oil Well Survey Co.

Methods of and Apparatus for Transmitting Intelligence to the Surface from Well Bores. A system for transmitting to the surface a signal indicating the orientation of a whipstock by attaching to the whipstock a radio transmitter controlled by a rolling ball switch or compass switch and coupling the transmitter to the drill pipe.

520—WELL SURVEYING

U. S. No. 2,484,151. R. F. Brownell. Iss. 10/ 11/49. App. 3/12/48.

Distance Measuring Device. A distance-measuring device having two wheels and sprockets connected by a calibrated perforated belt.

U. S. No. 2,488,277. C. J. Falk, R. K. Fairley and T. T. Short. Iss. 11/15/49. App. 6/15/48. Assign. General Electric Co.

Magnetic Wire Footage Meter. A magnetic wire footage counter having an electromagnetic marking head and an electromagnetic pickup head a fixed distance apart and arranged that the marking head is excited when a mark passes the pickup head and the pulses also counted, the gain of the pickup amplifier being controlled by the repetition rate of the pulses so as to correct for amplitude variations caused by changes in speed of the wire.

REVIEWS

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Seismicity of the Earth and Associated Phenomena, by B. Gutenberg and C. F. Richter. Princeton Univ. Press, 273 pp. 1949.

This volume is practically a necessity for any seismological observatory and should be of considerable value to underwriters of earthquake insurance in all parts of the world. It furnishes an unusually complete statistical picture of the seismicity of the earth. This is important, because major earthquakes occur chiefly in areas of previous seismic activity. In addition, the book constitutes an excellent survey text on the subject of earthquakes, furnishing a very complete list of references as well as a compendium of most of the large earthquakes of the forty years previous to 1947 and includes their epicenters and origin times. Tables listing the most important shallow focus or normal earthquakes, earthquakes of intermediate focal depth, and deep focus earthquakes are included in this book. Regional lists are also included of shallow earthquakes for each of 48 geographical regions, and of intermediate and deep focus earthquakes for each of 31 geographical regions, as well as a tabulation of active volcanoes.

Since the epicentres and origin times for the earthquakes listed are based on instrumental readings at various stations, the authors have drawn on individual station bulletins as well as on such compilations as the International Seismological Summary published at Oxford University, the Bulletin of the Union Géodèsique et Géophysique International published by the Bureau Central at Strasbourg, the Preliminary Bulletin of the Jesuit Seismological Association, and the Seismological Bulletin of the U. S. Coast and Geodetic Survey. Epicenters, origin times and focal depths listed in any of the data compilations were accepted only after careful inspection and possible revision.

The book contains world maps showing the epicentres of class "a" shallow earthquakes, and class "a" and "b" deep focus earthquakes. These maps emphasize the high seismicity of the Circum-Pacific Belt compared with that of the balance of the world, and the localization of deep focus shocks. In addition, there is a wealth of detailed maps of the fifty-odd geographic divisions into which the authors have separated the earth's surface. The authors have devoted considerable attention to the frequency of earthquakes both regionally and over the whole earth. They find that on the average a million true earthquakes occur per year, releasing energy of the order of 10^9 kilowatts, which is of the same order of magnitude as the estimated annual flow of heat from the interior to the surface of the earth.

There is a brief but pointed discussion of the overall structure of the earth, with special emphasis on crustal structure. Continental structure, with its associated sedimentary, granitic, and basaltic layers attaining a maximum overall thickness of 80 km. under some mountain masses, is contrasted with Pacific basin type structure, where the granitic layer is absent and the basaltic layer is covered by a very thin sedimentary veneer.

The volume concludes with a discussion of tsunamis, that is sea waves of seismic origin, and some consideration of the mechanism by which earthquakes relieve the stresses in the crust of the earth. This chapter more or less synthesizes the relation of earthquakes to our present knowledge of the earth's architecture. All in all the book is an invaluable and authoritative addition to recent literature on the earth sciences.

CORNELIUS G. DAHM

"Union Géodésique et Géophysique Internationale, Association de Seismologie. Comptes Rendus des Séances de la Huitiéme Conférence a Oslo (17–28 August 1948). Strasbourg (1949) (Minutes of the meetings of the Seismological Section, International Union of Geodesy and Geophysics, at Oslo, August, 1948)., 192 pp.

The Oslo conference of the International Union of Geodesy and Geophysics in 1948 was the first general meeting of this outstanding organization since the ill-timed sessions at Washington in September 1939. Because of the obvious need for international cooperation in earthquake seismology, the Union's Section on Seismology has performed a most vital function in providing a clearing house for seismologists of all nations. The numerous technical papers are presented only as abstracts or summaries, but the progress reports submitted to the Union by the representatives of each member nation are printed in full and taken together comprise an excellent summary of the world's seismological activities (exclusive of Russia) during the interval 1939–1948.

The presidential address by Robert Stoneley, noted British seismologist, is mainly a resume of the problems still faced by members of his profession. "It is the aspiration of seismologists," he says, "to be able to interpret in detail the whole record of an earthquake." This statement will undoubtedly sound familiar to those who have undertaken to interpret the usually simpler records from artificial earthquakes created in seismic prospecting. He paints so pessimistic a picture of the difficulties and complexities involved in the complete analysis that the reader is left with the feeling that the aspiration is a vain one for the foreseeable future.

The original papers were much too diversified in scope for enumeration here although a larger number appeared to be on microseisms than on any other single subject. As might be expected, there was virtually nothing on seismic prospecting. Many of the reports from the member nations indicate how seriously the war interrupted the continuity of recording at many of the world's leading seismological stations. The difficulties ranged from shortages of photographic paper to destruction of entire stations by bombing. The Japanese report expresses regret that the wartime incidence of destructive earthquakes in Japan was not reduced in the same measure as the recording facilities.

The minutes are mainly in French and English, with one report in Spanish. Many of the proceedings are reported alternately in French and English, the language switching either way between successive paragraphs.

MILTON B. DOBRIN

Canadian Geophysical Bulletin, National Research Council of Canada, Vol. 3, No. 1 (January–March, 1949).

Issued quarterly by the Associate Committee on Geodesy and Geophysics of the National Research Council of Canada, the Canadian Geophysical Bulletin summarizes current Canadian geophysical activity and provides a bibliography, with reviews, of recent publications relating to geophysics in Canada. This issue of the Bulletin covers the work carried on during the first quarter of 1949. Both governmental and commercial investigations are covered.

From this issue one learns that the structure of the Canadian shield is being studied seismically southward and eastward of Kirkland Lake utilizing mine blasts and rock readjustments, a project in part paralleling the location of fault blocks in the South African Rand using the seismic recordings of mine blastings. Further active study by seismic means of the rock burst problem within the mines at Kirkland Lake and Sudbury has been discontinued.

Airborne magnetic work was carried out by the Ontario Department of Mines in an area of lenticular magnetites, latitude 44°20′ to 45°15′, longitude 77°30′ to 78°00′, and in the Allard Lake area, north shore, lower St. Lawrence, where titanium bearing ilmenites are found associated with anorthosite intrusions into paragneisses. In the latter case no new deposits were found, but there were clear indications over the known ore bodies. The marked north marginal lows clearly evidenced the flat south dip of the ilmenites. Airborne work at Kirunai in Sweden by the Hans Lundberg Company located promising anomalies in an area where considerable surface work had already been done. The same company mentions further experimental work with airborne and mobile electrical methods re-

cording changes in electromagnetic field. Ground magnetic work by the Ontario Department of Mines in a prospective gold area, Groundhog River, failed to separate a broad rhyolitic series from bordering andesites.

The work of the Dominion Observatory in extending its network of magnetic stations in the Arctic locates the north magnetic pole in Northern Prince of Wales Island and indicates that it is moving northward at approximately 5 miles a year.

A test of Shoran by comparison with geodetic triangulation over established geodetic lengths of over 200 miles indicated a possible accuracy of better than 1 in 30,000, requiring, however, 16 single line crossings. This is a very acceptable standard for secondary triangulation and should permit control to be extended rapidly into North Central Canada. Field gravimeter exploration work was conducted during the past year at the Labrador iron deposits, East Sullivan, Quemont and Lynn Lake sulphide deposits, and in Alberta and Saskatchewan.

Field exploration for uranium has utilized essentially portable Geiger counters applicable only through a foot or so of cover. It is noted that the presence of rocks containing K^{40} may give high Geiger recordings. Tests of the radioactivity of certain batholithic bodies give some evidence that there can be increased radioactivity associated with hydrothermal mineralization.

ARTHUR A. BRANT

Prospecting for Uranium. Published by the U. S. Atomic Energy Commission and the U. S. Geological Survey, pp. 123. (1949).

This pocket-sized, carefully worded booklet provides authoritative information for prospectors and other interested persons wishing to obtain a general knowledge of all phases of the occurrence, identification, and sale of uranium-bearing ore. Uranium is the only naturally occurring substance that can be used today as a basic raw material in the large-scale production of atomic energy. Although more than 100 uranium-bearing minerals are known to exist, the main production of uranium comes from (1) the primary minerals pitchblende and uraninite, which are characterized in general by a dark brown or black color, a dull, pitchlike luster, and a high specific gravity and are usually found in vein deposits or pegmatities, and (2) several secondary minerals, including carnotite, which are characterized by bright yellow, orange, and green colors and which may occur in almost any rock type, usually as earthy or powdery masses, as groups of very small crystals, or as flat plates.

Vein deposits of uranium, which occur in the Great Bear Lake (Canada) and Katanga (Belgian Congo) regions, usually form well-defined mineralized zones. They consist predominantly of pitchblende accompanied frequently by sulfides of cobalt, nickel, bismuth, and copper, and possibly one or more of the precious metals (gold, silver, platinum), as well as secondary uranium minerals. Deposits of uranium in sedimentary rocks, notably sandstones, shales, and phosphates, possess unique characteristics. Deposits in sandstones, such as are found in the carnotite ores of the Colorado Plateau region, usually occur discontinuously over comparatively large areas. The individual ore bodies differ from each other in size and grade, and are spotty in distribution. In contrast to this type, deposits in shales, which occur in Sweden, the Soviet Union, and Tennessee, and deposits in phosphates, occuring for example in Idaho, Montana, and Florida, are usually continuous throughout an entire layer or bed and are rather uniform in grade and thickness. However in the latter cases their grade is usually lower than that of the Colorado Plateau carnotite deposits. Except where uranium occurs with thorium minerals, placer deposits of uranium are rare. Most pegmatites contain insufficient uranium to make it feasible to mine them for this metal.

Prospecting for uranium in the field involves tests for either fluorescence or radioactivity. Although most uranium minerals in their natural state do not fluoresce in ultraviolet light, a bead test using lithium fluoride or sodium fluoride gives a bead that fluoresces to a bright yellow green if as little as 0.05 per cent of U_3O_8 is present. As the bead test has certain limitations, it is used most effectively when combined with radioactivity tests, such as photographic scintillation, electroscope, and Geiger-counter tests.

When the Geiger counter is used in prospecting, the first step should be to establish the back-

ground count for the general area under observations. This count, caused mainly by cosmic rays and partly by minute quantities of radioactive elements that are present nearly everywhere on earth, varies with the sensitivity of the counter and with the topography and geology of the area. In general, the background count is higher over some rocks, granite for example, than over others such as limestone. During reconnaissance work, if an area is found in which the counter registers two or three times the background count a close examination should be made to determine the precise source of the radioactivity and to ascertain whether a grid should be established and a radioactivity contour map compiled. As it is not possible to say what minimum reading a counter should give to indicate commercial quantities or grades of uranium ore, it is a matter of primary importance to obtain readings in a specific area in terms of the background count. If the radioactivity of any particular rock is four times the background count, a representative sample should be taken for testing by a commercial assayer or by a Government agency.

When uranium is found in commercial concentrations, it may be mined and sold either to the U. S. Atomic Energy Commission directly or to any other person or company within the United States provided both the buyer and the seller are licensed by the Commission. Detailed instructions on licensing procedures, how to sell uranium ores to the Commission, the grades of ore desired and prices paid for them, as well as regulations covering the $10,000 bonus payment, public land laws, and special government rights and powers relating to uranium are also given in the booklet.

KENNETH L. COOK

Grundzulge der angewandten Geoelektrik (Fundamentals of Geoelectrical Prospecting) by Doz. Dipl. Ing. Dr. Volker Fritsch. Published by Manzsche Verlags- Und Universitatsvuchhandlung, Wien 1949, 412 pp.

This book is very useful as a reference and presents a systematic and thorough review of almost every geoelectrical method that has been used in applied geophysics. It is the only book of this type in the field of electrical prospecting with which the reviewer is familiar. In keeping with the detailed and extensive presentation of these many methods, an exhaustive bibliography of approximately 1,000 items is included. This bibliography should be particularly useful to those engaged in research in geoelectrical methods, as well as in its application. However, as might be expected in a compilation of this scope, certain minor discrepancies appear. For example, no reference is made in Section 1, which includes other reference works and compendia, to Chapman and Bartel's comprehensive treatise on geomagnetism. In addition to the chapters in their work that deal with geoelectrical methods and theory, both from the pure and applied phases, it is difficult to see how geomagnetism can be ignored when endeavoring to work with geoelectricity because the two are inseparable.

Although this work deals primarily with geoelectrical methods, the introductory chapter includes a very interesting discussion, that might be called almost philosophical in nature, regarding the limitations and potentialities of geophysical methods in general, as well as defining both pure and applied geophysics. The opinion is also expressed that geophysical methods can never have unique solutions and that oil, water and minerals cannot be detected directly because the values of the various physical characteristics of these materials overlap.

This volume would be a very worthwhile addition to the library of any practicing or teaching geophysicist, geologist, and civil engineer, irrespective of some of the constructive criticism that appears in the remainder of this review. It is unfortunate that language difficulties will probably limit the wide spread use of this book. However, a factor tending to mitigate this action is that it contains over 400 sketches, illustrations, and both schematic and circuit diagrams of the equipment used and the results obtained. The mathematical treatment is rather simple and for the most part involves only a knowledge of algebra and trigonometry.

In spite of the all-inclusive nature of this book, the reviewer believes that a separate section on anisotropic effects and telluric current phenomena would have added greatly to its usefulness, although references to these subjects are made. Similarly, the difficulties frequently encountered with polarization effects of electrodes do not seem to be sufficiently stressed even though a separate section

is devoted to the effect of meteorological factors on reproducibility of observations, particularly of resistivity measurements.

One of the few geoelectrical methods which does not receive the detailed treatment that it might is the one utilizing electrical transients. This subject is covered in approximately four pages although the reason for this brief treatment given by the author is that "Zur Zeit stehen alle diese Methoden noch mitten in der Entwicklung, wenngleich es an praktischen Erfolgen schon nicht mehr fehlt," (these methods are still in the development stage, although having proved themselves to have practical application). Most of this space is used in describing in some detail the work of Braun and the methods of Klipsch, and briefly touching upon that of Statham. No mention is made of the work of Evjen, Lewis and Blau although some of their papers are listed in the bibliography. In addition, in this connection, one reference to Lewis is incorrectly listed as Bradley, L. W., instead of Lewis, Bradley W.

A very interesting chapter on interpretational methods, including the semiquantitative aspects and the discussions of actual field applications, is also presented as well as one on special problems in geophysics, hydrology, mining and foundation engineering. The use of electrical methods in determining the thickness of glaciers, the presence of caves, mine workings and buried conduits, and in the study of lightning is included in this chapter. A chapter is also included which describes the principles involved in planning geophysical surveys in general, and geoelectrical methods in particular, with a section on cost factors.

RICHARD A. GEYER

"Recent Advances in the Technique of Submarine Gravity Surveying," R. I. B. Cooper, Proceedings of the Royal Society, Series A. V. 197. pp. 523–45.

The advances discussed in this paper are (1) a servo-mechanism for stabilizing the Meinesz Pendulum Apparatus, (2) an automatic depth recorder capable of recording to about 1 foot, (3) Decca navigation scheme, and (4) taut wire measurements of distance travelled by the submarine over the ground.

Meinesz showed that if two isochronous pendulums were swung from the same support with a 180° phase difference, the sway of the support could be eliminated. He also showed that the difference between the deflections of two isochronous pendulums swinging from the same support was unaffected by a motion of the support to a first order, provided the period of motion of the support is long compared to that of the pendulums. He used these two principles in his submarine gravity apparatus, swinging three isochronous pendulums from the same support. In observations at sea the center pendulum is left motionless and the two outer pendulums are started with equal amplitudes in opposite phase. The difference between the motion of each outer pendulum and the central pendulum is obtained optically and the resultant trace called a "fictitious" pendulum. Among the corrections to be applied are those for arc:

$$\delta T_2 = 1/16 T_1 (a^2 + a_2^2 + 3a, a_2 \cos(\phi_2 - \phi_1) + 2a_2^3 \cos^2(\phi_2 - \phi)$$

and for deviation from isochronism:

$$\delta T_2 = (T_2 - T_1 a, a_2 \cos(\phi_2 - \phi)/a$$

where T_1, T_2 = periods of respective pendulums; a, a_2 = amplitudes of fictitious pendulum and pendulum 2; and ϕ, ϕ_2 = phases of same.

Cooper shows that under distrubed conditions these corrections can be large, but that if suitable means are employed to make $a_2 = 0$, these reduce to

$$\delta T_1 = 1/16 T_1 a^2$$

and

$$\delta T_2 = 0.$$

He then deduces the necessary design equation for a suitable servo-mechanism utilizing a part of

the light beam of the middle pendulum trace, i.e., that which measures a_2, as a control element, keeping the practical limitations of design in mind.

The apparatus used to achieve the results fed the part of the light beam from the middle pendulum through a paddle-wheel chopper, then to a photocell. The output of the photocell was amplified in a two stage amplifier, rectified, and fed to a power amplifier and cathode follower which operated an electromagnet. The electromagnet was mounted on the gimbal frame and attracted an armature mounted on the pendulum apparatus.

Tables are given comparing observations with and without the stabilizer for artificial disturbances and for the base-station swings before and after the cruise. The maximum discrepancy of these tests, equivalent to 1.2 milligals, was obtained between the means of four runs with the stabilizer and four without on the final base-station swings. At sea, the gravity differences between swings with the stabilizer were $+1, -3, -5, 0, -2, -2, +1, +0.5$, and -4 milligals for respective runs.

Two attempts were made to take observations on the surface in exceptionally calm weather. In both cases the knife edges slipped on the supporting planes. It is surprising that large changes of period were not observed after these tests.

It can hardly be said that the stabilizer has been given an adequate test, for the author states in another place: "During the cruise such fine weather was experienced that the second order corrections even on shallow dives were smaller than the probable error of uncorrected gravity." It is doubtful if the time saving in the record computations is sufficient to make it desirable to provide the additional space and maintenance that this stabilizer would require.

The automatic depth recorder is described as recording from an aneroid bellows the differential pressure between an air chanber set to approximately the mean depth of the dive at the start of each dive and the pressure outside the vessel. A rubber diaphragm separater is used to transmit the sea pressure to an air column connected to the aneroid element. The movement of the bellows is recorded electrically on an Esterline-Angus milliameter. Calibration is accomplished by injecting small quantities of compressed air to the air chamber and recording the pressure change in the chamber by a suitable gauge, the recorder responding with a shift of axis. The scale is 2 mm/ft with a range of ± 25 feet. Wave fluctuations are recorded as well as depth fluctuations. It is clear that a depth recorder is a great asset to submarine gravity surveys and should be included on all future cruises.

The Decca navigation system is not described in detail. It uses the phase difference between master and slave stations to place the observer on a system of hyperbolas. It is difficult in general to keep track of unit phases or "lane numbers" and is particularly difficult in the case of submarines. A system of lane identification is in existence but not available for these observations. Positional accuracy of 50 yards is claimed. Whenever possible navigational systems such as Decca or Loran should be used for all gravity surveys at sea.

The taut wire gear consists of an 18-pound cast iron sinker attached to a 0.75 mm. wire. This sinker can be ejected from a submerged submarine. After the sinker has lodged on bottom, the wire paid out can be measured on a meter wheel and a record of distance versus time kept. It is pointed out that this system can be used only in water depths that are small compared with distances travelled. It is claimed that variations in speed of one-half a knot east to west were observed at some double stations which would have led to errors of 2.5 mgal. Due to the extremely limited applicability of this method and the availability of radio navigation aids in most shallow water areas, this system will probably not be of great importance to submarine gravity measurements at sea.

Limited laboratory tests of the second order Browne terms are described, confirming the Browne theory for 5 second periods but giving anomalous results for 3.1 second periods. This latter result is probably due to periods of the order of those of the main pendulum being introduced by the crude experimental procedure.

J. LAMAR WORZEL
Columbia University

"Aerial Magnetic Survey of Vredefort Dome in the Union of South Africa," by Oscar Weiss, Mining Engineering, Vol. 1, No. 12, pp. 433–438, 1949.

This is an interesting demonstration of the mapping of geological structure by means of magnetic anomalies. The famous Witwatersrand system crops out near Johannesburg, dips southerly between younger series, then is exposed again sixty miles to the southwest where it surrounds the granitic Vredefort dome.

This dome is a huge, granite plug, twenty-five to thirty miles in diameter. Less than half the dome is exposed, since the rest is covered by younger dolerites and sediments. The Lower Witwatersrand shales give rise to strong positive anomalies at Johannesburg but cause strong negative anomalies of one to two thousand gammas when mapped at Vredefort by the airborne unit. (The author designates an anomaly positive when it increases the numerical value of the earth's main magnetic field.) The negative anomalies exist over all but the southern edge of the dome, where the anomalies are positive. The author submits that the negative anomalies are caused by negative polarization, and that the polarization is in turn the result of heating and deformation by sills that are known to have voluminously invaded the shales. This view is substantiated in part by gravity data from an older survey. The gravity anomalies are lower in the area of positive magnetic anomalies, thus indicating that here the shales do not contain the heavier sills. Furthermore, in the area of positive anomalies, the overlying Karroo sills are absent. Both the positive and negative anomalies are asymmetrically located with reference to the outcrops of the shales and they are used to confirm the geologically mapped dips which show the overturning of the shale system. Another application of the magnetic data is to predict that the almost vertically dipping shales will be cut off at depth by faults. Faulting would cause a system of opposite poles to be formed along the base of the shales. This is one way to account for the decrease in amplitude of the negative anomalies in the northeast.

The article is not exhaustive in its presentation of the geological and geophysical results but it is commendable because of the interesting relationships developed between the geophysical data and the geology. Some minor details may be criticized. For example, the author points out that a certain problem can be solved by recording the magnetic anomalies at two or three different heights. It should be noted here that if an anomaly is completely mapped at one elevation, no additional information is obtained by mapping it at another elevation. (Henderson and Zietz, in the October, 1949, issue of *Geophysics*, conclusively demonstrated that a map can be readily transformed to another elevation by computation). As for the author's magnetic map, it is somewhat unusual because the anomalies are restricted almost entirely to the edges of the dome. The map is contoured at 200 gammas and the surface rocks consist of various igneous and metamorphic units. It is surprising that the map is not more abundantly covered with magnetic anomalies. Also it would seem advisable to secure some shale samples and measure the direction and amount of their polarization in order to verify the surmise of negative polarization.

NELSON C. STEENLAND

"Sur les oscillations rapides du champ magnétique terrestre," by P. Giacomo, (On the Rapid Fluctuation of the Earth's Magnetic Field) Annales de Géophysique, Tome 5, no. 2, pp. 171–173 (1949).

The vertical component of the terrestrial magnetic field was recorded continuously over a ten day period at the Schavinsland Observatory in the Black Forest of Germany. The measuring setup consisted of a single turn loop of 250 meters (800 ft.) diameter connected to an aperiodic galvanometer. The time rate of change of the field was measured rather than the field itself.

The records showed two types of relatively rapid fluctuations:

1. Irregular fluctuations, of duration less than one hour, and a few γ/min. in amplitude. These same fluctuations could also be seen in ordinary magnetic measurements. Therefore this observation may be of interest to petroleum geophysicists.

2. Relatively regular oscillations of a few γ/min., the frequency of which is between 1 and 10 cycles per minute.

HUBERT GUYOD
Houston, Texas

"The Magnetic Field Within the Earth," by E. C. Bullard, Proc. of the Royal Soc. London, Vol. 197, No. 1051, pp. 433–453 July 7, 1949,

In 1919 Larmor proposed that the magnetic field of the earth might be maintained "in a way analogous to that of a dynamo." Bullard examines various systems that might cause motions within the earth and result in the interaction of currents and magnetic fields.

The slowing down of the whole earth by tidal friction is an obvious choice. In this slowing down process the core would be expected to lag behind the solid part but Bullard states that the induction caused by tidal motion produces no appreciable field so that the "field produced indirectly, by the slowing of the core, will be smaller still."

Irregularities in the rate of earth rotation have become known from the apparent errors they have caused in the positions of solar bodies, but neither slow changes, sudden changes, nor Newcomb's "great empirical term" have appreciable magnetic effects.

Precession and nutation are also examined. Nutation is at once dismissed as having negligible effect. Poincaré has shown that the ellipticity of the earth is sufficient to cause the earth to behave rigidly in precession and this demonstration is accepted for the time being.

Convection currents on the other hand are assumed to be of importance. They are considered to exist by reason of the radioactivity of meteorites. Furthermore Verhoogen has shown that a "rotating ellipsoid in hydrostatic equilibrium cannot also be in thermal equilibrium and must necessarily be subject to convection currents." By assuming a very moderate amount of radioactivity in the core, a system of four convectional currents is devised which completes a series of reactions that culminate in the reinforcing of the earth's dipole field. First the rotating material within the core intersects the dipole field. The resulting currents produce a field which is in turn intersected by the core material in convectional motion. The currents thus created produce a field which again interacts with core material in spinning motion. This induces currents that produce a field in turn cut by material in convection to produce still another current whose field now supplements the original dipole field.

Thus, Bullard postulates a chain reaction, the existence of which started with a very small dipole field and built itself into an essentially steady state system. This system contains a toroidal field many times larger than the dipole field. Elsasser first proposed this chain reaction but thought it too complicated to be convincing. Bullard, however, demonstrates that the chain is quite acceptable after some general and unforced reasoning. The article does not purport to contain a rigid mathematical proof of the existence of all the currents and fields which are proposed. This proof, involving Maxwell's equations, is outlined in part and is expected to be completed in the near future.

NELSON C. STEENLAND

"Variation periodique de la gravité en un lieu." (Periodic Gravimetric Variations at a Given Station) by R. Bollo and A. Gougenheim. Annales de Geophysique. Tome 5, No. 2 (1949), pp. 176–180.

The purpose of the measurements in France reported by the authors was:

1. To check the reliability of "North American" gravimeters, and
2. To investigate the changes of gravity at a station, caused by the sun and moon (tidal effect).

Similar experiments have been and are still being made in the U. S. and, to my knowledge, workers here also base their calculations on either of the following concepts: Rigid earth and actual, viscous earth. It is shown in the paper that the variation of gravity for these two earths caused by solar and lunar tides is in the ratio of 1: 1.147.

HUBERT GUYOD
Houston, Texas

"Isostasy and its Meaning," by Beno Gutenberg. *Tellus*, vol. 1, no. 3, pp. 1–5 (1949).

Ever since the initial development of the theory of isostasy by Pratt and Airy almost a century ago, geologists have used the concept to interpret surface observations in terms of crustal adjustments to excesses and deficiencies of gravitational loading. With the very considerable amount of gravity data now accumulated, there has been a tendency for geologists to lean heavily on small departures

from isostatic equilibrium to support various tectonic arguments. In this brief paper, Gutenberg cautions those who make use of published isostatic anomalies as a basis for geologic deductions to bear in mind that such anomalies are often less precise and reliable than is generally realized. The difficulty lies not so much in any inaccuracy of the gravity observations from which the anomalies are calculated as in the reliability of the asumptions used in the calculations. Whatever the type of isostasy postulated, whether Pratt or Airy or something in between, it is necessary to assume a functional relation between density and depth down to about 100 km.

Any estimate of density at depths greater than a few kilometers is obviously risky, but it is generally agreed, according to Gutenberg, that Heiskanen's density assumptions based on seismological evidence are most reliable. Reductions using them, however, are highly laborious and probably not feasible for organizations that must reduce great quantities of field data with limited computing personnel and facilities. For this reason, the more recent tendency has been to assume a uniform specific gravity of 2.67 and a uniform thickness of 30 km for the earth's crust, whether Atlantic, Pacific or continental. The supporting substratum is similarly assigned a uniform density of 3.27. This simplifying procedure, Gutenberg points out, can easily lead to errors of the order of 10 milligals. Densities and thicknesses in the crust vary substantially from one area to another and laboratory evidence is cited which indicates that the density contrast between crust and substratum is actually about one third smaller than is assumed in the simplified isostatic calculations.

The mechanism of isostatic adjustment is considered briefly in terms of flow processes. Although data on flow of material within the earth is very sparse, it appears that flow processes on the surface, such as erosion or sedimentation, which are slow compared with the crust's relaxation time, about 10,000 years, should not yield substantial gravity anomalies, while those, such as accumulation of glacial ice, which take place more rapidly, would be expected to produce measurable anomalies until equilibrium is again approached.

Gutenberg's paper is essentially expository and contains no new data. It presents a point of view, however, which might well be taken to heart by those who draw extensive conclusions from reported isostatic deviations without having examined and evaluated the assumptions upon which the deviations were ascertained.

MILTON B. DOBRIN

"Seismic Experiments on the North German Explosions, 1946 to 1947," by P. L. Willmore. Phil. Trans. Royal Soc. London, Ser. A No. 843, Vol. 242, pp. 123–151 (1949).

Although earthquake data have provided us with most of our knowledge of the earth's interior beneath the base of the crust, they seldom give any reliable information on the composition, layering, and thickness of the crust itself. Seismic measurements on large, planned artificial explosions are much more suitable for crustal investigation. The time and location of the shot can be established to a much greater degree of precision than is obtainable with earthquakes. In addition, it is possible to station detecting instruments at any desired distances from the explosion in advance of its occurrence. This provides an opportunity for much more detailed time-distance data than can generally be expected from near earthquakes. Until the end of World War II, only quarry blasts were available for such seismic experimentation and these almost never had enough energy to generate seismic waves that could penetrate the entire crust. Since the war, however, a number of military operations have provided excellent opportunities for deeper investigation. The various atomic bomb tests, such as those in New Mexico and at Bikini, gave useful seismic data both at specially established field stations and at regular observatories. Blasts to destroy large amounts of surplus Navy explosives at Arco, Idaho and Solomons, Md. have been received on special seismic detectors laid out in profiles hundreds of miles long and have given valuable information on the crustal layering in both areas.

Willmore's paper is one of several which have recently appeared on the seismic data from the greatest non-atomic planned explosion of history, that at Helgoland on April 18, 1947. Using 4,000 tons of high explosives, the British Navy destroyed the German fortifications and stores on this island with one blast for which seismograph observers all over western Europe stood by. The Royal Society of London established four profiles of special field stations radiating from the shot, the farthest unit

being about 315 kilometers away. An American group, comprising personnel of the Naval Ordnance Laboratory and the Office of Naval Research, set up ten stations along a 1,000 km profile extending to Trieste. In addition the shock was received on hydrophones from two ships in the North Sea and on the permanent equipment of numerous European seismological stations located as far as 1,000 km from Helgoland. Reporting to the Royal Society, Willmore makes use of all data except that collected by the Americans, whose report is now being completed. Some of the same records that Willmore studied were analyzed and interpreted by Mintrop.* Because no instruments could be placed closer than 50 km to Helgoland, Willmore includes additional data obtained from series of nearby explosions at Soltau by seismographs 2 to 50 km away to increase the accuracy of the interpretation.

The experimental results are embodied in the usual travel-time vs. distance plots. First arrivals yield well defined segments corresponding to layers of different velocity within the crust. The highest indicated speed is 8.1 km/sec which agrees closely with the speed of the P_n phase, (a wave refracted along the top of the substratum just below the base of the crust) previously ascertained from records of near earthquakes in western Europe. Less significance is attributed to velocities deduced from subsequent events on the records. The author acknowledges the danger of drawing lines through the almost random array of points representing later arrivals and sets up statistical tests that give some feeble justification for the lines finally drawn.

In computing depths from the intercept times and apparent speeds, the author makes the equivalent of a weathering correction for the less consolidated sedimentary formations covering the hard rocks below. No special refraction shots were laid out for this purpose since sufficient data were available from previous commercial shooting in the area. There is also a perfunctory attempt to map differences in the thickness of the layer just below the low-velocity material. The procedure is admittedly somewhat arbitrary because of difficulties in separating contributions to the intercept time from the explosion and detector ends of each trajectory.

It is interesting to compare Willmore's conclusions with those of Mintrop, since both were based to a large extent upon the same records. Each obtains evidence of three layers above the P_n zone. Neither the velocity nor interface locations coincide for the two interpretations. However the total thickness of the three layers is almost the same for both. Willmore computes it as 29.9 km, while Mintrop obtains 28 km. The former author presents no evidence for a 9.2 km/sec segment which Mintrop postulates on the basis of a single time-distance point as representing a "P_{n+1} layer" at a depth of 57 km. Willmore's time-distance curve gives data out to 1,000 km., while Mintrop's goes only to about 325 km If the 9.2 km/sec speed exists it should certainly show up on the longer time-distance curve, and its reality thus appears doubtful. Since Mintrop bases none of his support for his 16.3 km/sec layer at 180 km on Helgoland data, the fact that Willmore does not observe such a speed is not surprising. Willmore did not, as Mintrop did, seek to identify any of his arrivals as reflections from crustal or sub-crustal layers.

In addition to the travel-time data, the paper presents a tabulation of the total energy of the seismic waves generated by the Helgoland explosion as calculated from the amplitude of the ground displacement at a number of nearby stations. The energy is concluded to be of the order of 10^{17} ergs. This appears to be a considerable release of energy, but compared to the energy of the average earthquake it is small indeed. Gutenberg has shown that earthquakes the world over yield an average of 10^{17} ergs of energy every second.

Except for a sparsity of information on the instrumentation and for a scarcity of complete sample records on which the various plotted events on the time-distance charts are identified, the paper is quite comprehensive. The thoroughness tends to leave the reader in the position of having missed the forest for the trees. With all the inherent uncertainty in the data, however, the author cannot be blamed for the careful qualification of all his conclusions. It will be interesting to compare his results with those obtained by the American observers when their report is made available.

MILTON B. DOBRIN

* Mintrop, L., "On the Stratification of the Earth's Crust According to Seismic Studies of a Large Explosion and of Earthquakes," *Geophysics*, vol. xiv, pp. 321–336 (1949).

PUBLICATIONS RECEIVED

Listed below are all publications received at the Business office of the society on subscription and through free exchange for *Geophysics* since publication of the last issue. Periodicals and separates indicated by the asterisk (*) have been forwarded to the Special Reviews Committee, and will be placed in the permanent depository of the society at the University of Tulsa Library. These publications are available for loan to members of the society on application to the business manager. Other publications will be held for a short time at the Business Office. Disposition of books listed is made by the Special Reviews Committee.

Periodicals

American Journal of Science, Vol. 247, No. 11 (November, 1949), No. 12 (December, 1949) and Vol. 248, No. 1 (January, 1950)

**Annales de Geophysique* (Published in French by Centre National de la Recherche Scientifique), Vol. 5, No. 3 (1949)

**Annali di Geofisica* (Published in Italian), Vol. II, No. 3 (July , 1949)

**Az Állami Földmérés Közleményei* (*Communications of the Hungarian State Survey*), Vol. 1, No. 4 (1949)

The Bulletin of the American Association of Petroleum Geologists, Vol. 33, No. 11 (November, 1949) No. 12 (December, 1949) and Vol. 34, No. 1 (January, 1950)

**Bulletin of the Seismological Society of America*, Vol. 39, No. 4 (October, 1949)

**Canadian Geophysical Bulletin*, Vol. 3, No. 2 (1949) "Bibliography of Canadian Hydrology" and "Bibliography of Physical Oceanography for Canada"

**Committee on Geophysics and Geography of the Research and Development Board*, "Articles on Geophysics in Current Russian Periodicals," List No. 25, 16 January 1950

Economic Geology, Vol. 44, No. 7 (November, 1949) and No. 8 (December, 1949)

**Erdöl und Kohle*, Vol. 2, No. 10 (October, 1949), No. 11 (November, 1949) and No. 12 (December, 1949)

**Geofisica Pura e Applicata*, Vol. XV, No. 1–2 (Luglio-Settembre, 1949)

**Geophysical Exploration* (Published in Japanese by Society of Exploration Geophysicists of Japan), Vol. 2, No. 1 and No. 2 (1949)

Institute of Petroleum Review, Vol. 3, No. 34 (October, 1949), No. 35 (November, 1949) and No. 36 (December, 1949)

Instruments (Journal of the Instrument Society of America), Vol. 22, No. 11 (November, 1949), No. 12 (December, 1949) and Vol. 23, No. 1 (January, 1950)

Journal of Applied Physics, Vol. 20, No. 11 (November, 1949) and No. 12 (December, 1949)

**The Journal of Geology*, Vol. 57, No. 6 (November, 1949)

Journal of Geophysical Research, Vol. 54, No. 4 (December, 1949)

Journal of the Institute of Petroleum, Vol. 35, No. 309 (September, 1949), No. 310 (October, 1949) and No. 311 (November, 1949)

Journal of Petroleum Technology, Vol. 1, No. 11 (November, 1949), No. 12 (December, 1949) and Vol. 2, No. 1 (January, 1950)

Nafta (*Petroleum*), Vol. V, No. 9 (September, 1949), No. 10 (October, 1949) and No. 11 (November, 1949)

**Nuclear Science Abstracts*, Vol. 2, No. 12 (June 30, 1949), Vol. 3, No. 9 (November 15, 1949), No. 10 (November 30, 1949), No. 11 (December 15, 1949) and Vol. 4, No. 1 (January 15, 1950)

Physics Today, Vol. 2, No. 11 (November, 1949), No. 12 (December, 1949) and Vol. 3, No. 1 (January, 1950)

**Proceedings of the Cambridge Philosophical Society*, Vol. 45, Part 4 (October, 1949)

Review of Scientific Instruments, Vol. 20, No. 11 (November, 1949) and No. 12 (December, 1949)

**Tellus*, Vol. 1, No. 4 (November, 1949)

Separates

*"Erdmagnetische Messungen in der Schweiz," by Hans Röthlisberger (reprint from *Neuen Zürcher Zeitung*, No. 485—Beilage "Technik," March 9, 1949)

*"Untersuchungen über die Vitalität von Fischen," by Ulrich A. Corti and Max Weber (reprint from *Schweizerische Zeitschrift für Hydrologie*, Vol. 12, No. 1/2, 1949)

*"Beitrag Zur Messung von Erschütterungen," by Max Weber (reprint from *Helvetica Physica Acta*, Vol. 22, No. 4, 1949)

*"International Union of Geodesy and Geophysics: Minutes of the Eighteenth Conference Held at Oslo August 17 through 28, 1948," by J. P. Rothé, Secretary, Strasbourg, 1949

*"Minutes of the General Assembly at Oslo, International Associations of Seismology, Meteorology and Physical Oceanography, August 17–28, 1948"

Books

Appalachian Geological Society 1949 Bulletin, Vol. 1

Erdöl und Tektonik in Nordwestdeutschland (1949), published by Amt für Bodenforschung, Hannover—Celle, Germany

Exploration Geophysics (Second Edition, 1950), J. J. Jakosky

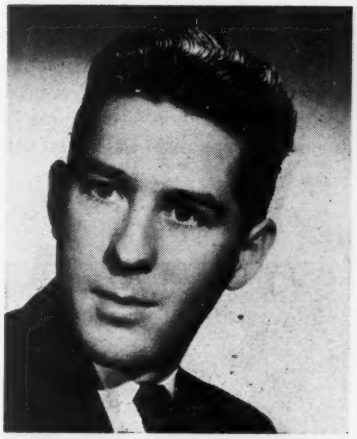
BOOKS ON SALE BY THE SOCIETY

Address *Geophysics*, Box 1614, Tulsa 1, Oklahoma. Books not listed will be supplied at prices quoted by the publishers.

Applied Sedimentation. Ed by Parker D. Trask. 1950. Pp. 674	$ 5.00
Barlow's Tables. By L. J. Comrie. 1944. Pp. 258	3.00
Chamber's Mineralogical Dictionary	4.75
Cumulative Index to Geophysics (1931–47). Paper—$1.50. Cl.—$2.50 (Members, $1 and $2).	
The Decibel Notation. By V. V. L. Rao. 1946. Pp. 179	3.75
Differential and Integral Calculus. By Francis D. Murnaghan. 1946. Pp. 502	6.65
Earth Waves. By L. Don Leet. 1950. Pp. 122	3.00
Exploration Geophysics. 2nd Ed. By J. J. Jakosky. 1950. Pp. 1200	12.50
Geophysical Case Histories, Vol. I. 1949. Pp. 680. $7.00 ($6 to members).	
High-Polymer Physics. Ed. by Howard A. Robinson. 1948. Pp. 572	12.00
Oil Property Valuation. By Paul Paine. 1942. Pp. 204	3.00
Principles of Field and Mining Geology. By J. Donald Forrester. 1946. Pp. 647	7.00
Problems of Petroleum Geology. Ed. by W. E. Wrather & F. H. Lahee. Pp. 1073	5.00

Postage paid on all shipments to members of SEG.

CONTRIBUTORS



C. C. BATES

C. C. BATES received his B.A. in geology from DePauw University in 1939 and the M.A. in physics and meteorology from the University of California at Los Angeles in 1944. From 1939 through 1941 he was in the geophysical department of The Carter Oil Company, working in Missouri, Mississippi, Kansas and Nebraska. From 1941 through 1945 he served in the U. S. Army and Air Force, specializing in oceanographic forecasting for amphibious invasions in European, China-Burma and Pacific war theatres. He was awarded the Bronze Star for oceanographic forecasting in connection with the invasion of Normandy, and upon separation held the rank of Captain.

In 1945 and 1946 he was Special Assistant to the President of the American Meteorological Society. Also in 1946 he was Oceanographic Technician with Woods Hole Oceanographic Institution for the Bikini Atomic Bomb Test. He joined the U. S. Hydrographic Office, Washington, in 1946, where he has held the positions of Technical Assistant to Chief of Division, Head (Acting) of the Programs Section in the Division of Oceanography, and Head of the Marine Geography Branch in the Division of Oceanography.

He was a partner in the firm of Bates and Glenn, Consulting Meteorologists, Washington, in 1947, and from 1948 to the present he has been consultant to A. H. Glenn & Associates, New Orleans, Louisiana.

He is a councilor for the National Association of Industrial Meteorologists and chairman of the Committee on Industrial, Business and Agricultural Meteorology of the American Meteorological Society. In addition to these societies, he is a member of The American Association of Petroleum Geologists, American Geophysical Union, American Polar Society, Geological Society of Washington, American Society of Limnology and Oceanography and Society of Exploration Geophysicists.

A. H. GLENN

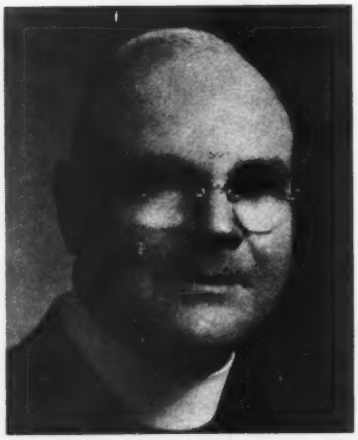
A. H. GLENN received the B.S. in civil engineering from the University of Wisconsin in 1942, and the M.S. in Meteorology from New York University in 1946. He did additional graduate study in oceanography at the University of California at Los Angeles in 1943, after being engaged in civil engineering for consulting engineers from 1939 through 1942 in Oklahoma, Texas, Wisconsin and Illinois. From 1942 through 1946 he served in the U. S. Air Force and was engaged in weather reconnaissance flights, and forecasting for construction and combat operations in the South-, Southwest Pacific and China-Burma-India theatres. Upon separation from the Air Force he held the rank of Captain.

From 1946 through 1948 he was Climatologist with the Air Weather Service in Washington, and a member of the Panel on Oceanography of the Research and Development Board, Governmental Advisory Committee on Oceanography.

At present he is a consulting meteorologist with A. H. Glenn and Associates, engaged in climatological, forecasting, and instrument services in the fields of

meteorology and oceanography. He is a councilor for the National Association of Industrial Meteorologists, and a member of the Editorial Board of *Meteorological Monographs* of the American Meteorological Society. He is a registered civil engineer.

Mr. Glenn is a member of the American Meteorological Society, Royal Meteorological Society, American Association for the Advancement of Science, American Institute of Metallurgical Engineers, American Association of Chemical Engineers, American Society of Limnology and Oceanography, American Geophysical Union and the National Association of Industrial Meteorologists.



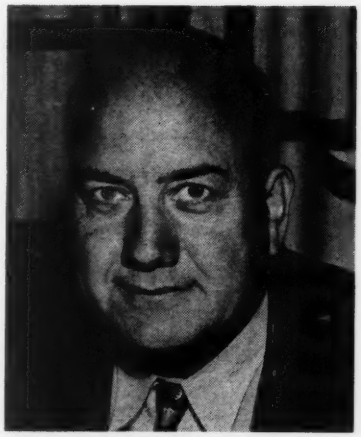
REV. JAMES B. MACELWANE, S. J.

REVEREND JAMES B. MACELWANE, S. J. (A.M., M.S., Ph.D., Sc.D.) is Dean of the Institute of Technology, Saint Louis University, Saint Louis, Missouri. He was born near Port Clinton, Ohio, September 28, 1883. He attended Saint John's College High School, Toledo, Ohio; Saint Stanislaus branch of John Carroll University, Cleveland, Ohio; Saint Louis University, Saint Louis, Missouri; University of California, Berkeley, California, and the University of Giessen, Giessen, Germany.

He was instructor and then Assistant Professor of Physics at Saint Louis University, 1912–1915. He held the position of Assistant Professor of Geology at the University of California, where he organized graduate study in geophysics and had charge of the seismographic stations of the University at Berkeley and at Lick Observatory on Mount Hamilton, 1923–25. In 1925 he was appointed Professor of Geophysics and Director of the Department of Geophysics in Saint Louis University, a position which he still holds. This was the first department of geophysics in the western hemisphere. He was Dean of the Graduate School, 1927–1933 and in the spring of 1944 he was appointed Dean of the new Institute of Geophysical Technology (now the Institute of Technology) of Saint Louis University, again the first of its kind in the western hemisphere.

Father Macelwane is a Fellow of the Geological Society of America and of the American Association for the Advancement of Science. He is a member of the National Academy of Science, Society of Exploration Geophysicists, American Institute of Mining and Metallurgical Engineers, American Physical Society, American Geophysical Union, American Meteorological Society, American Geographical Society, Seismological Society of America, Sigma Xi, Pi Mu Epsilon and others.

He has been chosen by his colleagues for offices of distinction in a number of scientific societies. He was President of the Seismological Society of America, 1928–1929, member of the Board of Directors, 1925 to the present, and of the Editorial Board of the *Bulletin*, 1932 to the present. He was Vice-President of the Section of Seismology of the American Geophysical Union, 1935–1938, and President, 1938–1941. He was Vice-President and Chairman of Section E, Geology and Geography, of the American Association for the Advancement of Science, 1934; Vice-President of the Missouri Academy of Science in 1936 and President in 1937; Vice-President of the Academy of Science of Saint Louis, 1935–1936 and President, 1936–1937; President of the Jesuit Seismological Association, 1926 to the present.



THOMAS C. POULTER

THOMAS C. POULTER is an Associate Director on the staff of Stanford Research Institute, Stanford, California.

A native of Salem, Iowa, Dr. Poulter has his B.S. degree from Iowa Wesleyan College (1923), his Ph.D. from the University of Chicago (1933), and an honorary Sc.D. from Iowa Wesleyan College (1935).

His teaching career included terms as assistant in biology, chemistry and physics (1923), head of the Department of Chemistry (1925–27), head of the Department of Physics (1927–32), and head of the Division of Physical Sciences, Mathematics and Astronomy (1932–33), Iowa Wesleyan College; assistant in chemistry (1923–25), University of Chicago; and lecturer at state universities in 14 western states and Canada (Summer of 1927).

Dr. Poulter was second in command and senior scientific advisor on the second Antarctic Expedition of Rear Admiral Richard E. Byrd during 1933–35. He was a John Simon Guggenheim Fellow for the first year of his stay in the Antarctic.

For his work and scientific advancements with the second Byrd Expedition, Dr. Poulter was awarded a Special Gold Medal by the National Geographic Society in April, 1937, and a special Congressional Medal, voted by the United States Congress on January 19, 1938, "For scientific accomplishment unequalled in polar exploration."

Dr. Poulter made a second trip to the Antarctic in 1939–40 as scientific advisor to an United States Antarctic Service Expedition. For his services with this expedition, he was awarded a Second Congressional Medal on June 13, 1947, "in recognition of valuable service to the Nation by courageous pioneering in polar exploration which resulted in important geographic and scientific discoveries."

He designed the Antarctic Snow Cruiser for the Antarctic Service Expedition.

He is a Lieutenant Commander in the Naval Reserve and has participated in several research projects for the armed services.

Before coming to Stanford Research Institute, Dr. Poulter was Associate Director of the Armour Research Foundation in Chicago. He was given the Armour Research Foundation Recognition Award on June 27, 1945.

Dr. Poulter's outstanding recent work has been the development of the method of geophysical seismic exploration bearing his name.

His special fields of research and study are: organic chemistry; electrical, chemical, physical and optical effects at extremely high pressure; Antarctic meteor and auroral phenomena; glaciology; seismology; and terrestrial magnetism.

On June 16, 1948, Dr. Poulter was awarded honorary membership in Sigma Pi Sigma, national honorary society in physics. He is a member of the American Physical Society, the National Research Council, Society of Exploration Geophysicists, and a number of societies and associations in his scientific fields.

CARL H. SAVIT

CARL H. SAVIT was born in New York in 1922, and has resided in New York, Medellin, Colombia, and Los Angeles. His undergraduate work included mathematics and physics, and he did graduate work in mathematics and statistics at California Institute of Technology. For four years he was a teaching fellow in Mathematics at California Institute of Technology. He has done research work in statistical meteorology, statistics and upper atmosphere physics. In the U. S. Air Force he served as Project Officer with the Aircraft Radiation Laboratory at Wright Field, Ohio, and at Alamogordo, New Mexico he was engaged in research on propagation of radio waves. He has been associated with Western Geophysical Company since 1948.

He is a member of the American Mathematical Society, American Mathematical Association and Society of Sigma Xi.

M. M. SLOTNICK was graduated from Harvard University with a Ph.D. in Mathematics in 1926. He had done his undergraduate work at the same institution. As a Travelling Fellow in Germany and a National Research Fellow at Princeton, he did further graduate work. After some teaching he joined the Humble Oil and Refining Company in 1930 in the Geophysical Research Section. In 1936 he was transferred to the Geophysical Exploration Division of that organization, in which he is at present engaged in the capacity of developing and supervising interpretation techniques.

As a member of the Society of Exploration Geophysicists, Dr. Slotnick served as Editor from 1937 to 1939.

M. M. SLOTNICK

SULHI YÜNGÜL

SULHI YÜNGÜL was born in Turkey and was one of the students selected by the Turkish Government to be educated abroad. In 1938 he went to the School of Mines in Paris and after World War II he came to this country. He received his B.S. in Mining Engineering from the Montana School of Mines in 1943, his M.S. in Geological Sciences in 1944 and Geophysical Engineer's degree in 1945, both from the California Institute of Technology. Since then he has been in Turkey working for M.T.A. Enstitüsü as resistivity party chief, chief geophysicist and the supervisor of gravity and seismic parties.

He is a member of the American Geophysical Union, and of the Geological Society of Turkey; an associate member of the Society of Exploration Geophysicists and of the Sigma Xi; and a junior member of the A.I.M.E.

In addition, references are cited to earlier issues for the biographies of: W. B. Agocs, Vol.XIV, No. 2 (April, 1949) and Lorenz Shock, Vol. VII, No. 4 (October, 1942).

SOCIETY ROUND TABLE

ANALYSIS OF SOURCES OF PAPERS APPEARING IN *GEOPHYSICS* FROM 1936 THROUGH 1949

Geophysics is now entering its 15th year of publication. An analysis of the sources of the published papers should prove both interesting as well as useful as a guide to future publication policies of those organizations who are potential contributors. Four hundred and fifteen technical papers were published during the period 1936 through 1949. A detailed summary of the sources of papers on an annual basis is presented in Table 1. Service and oil companies contributed in almost equal proportion, with universities, several government agencies, and individuals contributing only 20 per cent of the papers published. In this connection it is interesting to note that although the total number of papers pub-

TABLE I

Source	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	Total	Percent
Oil Companies	9	4	8	11	13	10	18.5	10	9	13	11.5	18	16	14	165	39
Service Companies	15	13.5	15	12	13	18	10	9	7	13	14.5	9	12	5.5	166.5	41
Universities	3	3.5	0	3	4	2	1	4	7	2	3	2	6	6.5	47	11
Government Agencies	0	1	0	0	2	0	0	1	1	0	5	2	2	3	17	4
Individuals	3	1	1	2	1	1	1.5	1	1	1	1	2	2	1	19.5	5
Total	30	23	24	28	33	31	31	25	25	29	35	33	38	30	415.0	100

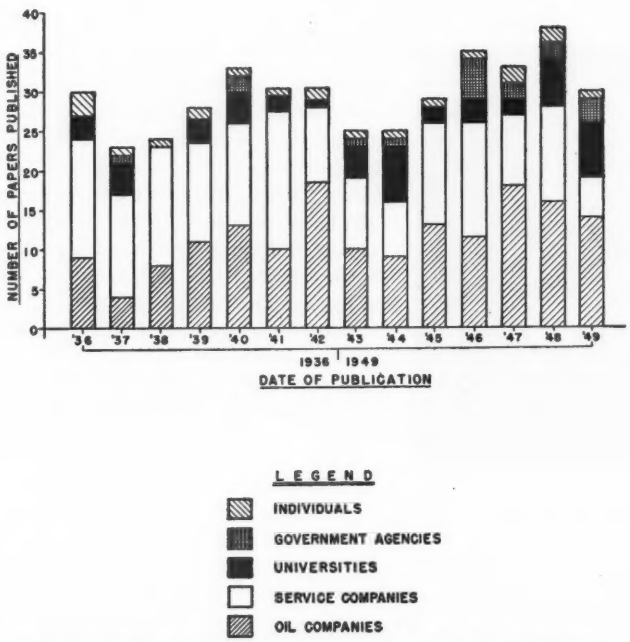


FIG. 1. Number and origin of papers published annually in Geophysics from 1936–1949.

lished by service and oil companies over this period is almost equal, the ratio varied appreciably at different times. These relationships may be seen graphically in Figure 1.

Similarly, although 29 oil companies and 50 service companies contributed 165 and 166½ papers, respectively, for an average of approximately 5 and 3 papers each, the number of papers published was

not necessarily distributed evenly throughout the 15 year period. The variation in the rate of publication for this time for several of the service and oil companies is shown in Figure 2. Because average values as such frequently fail to highlight some of the more significant facts in a situation, Figure 3 was prepared to illustrate the frequency distribution of papers published by these two groups.

It is evident from Figure 3 that a few oil and service companies have contributed a substantial proportion of the papers published. Perhaps it is in order at this point to insert a quotation from a recent Presidential Address (1946)[1] in connection with obtaining papers for Volume I of Geophysical Case Histories, to the effect that "Every oil company has benefited by and no company which con-

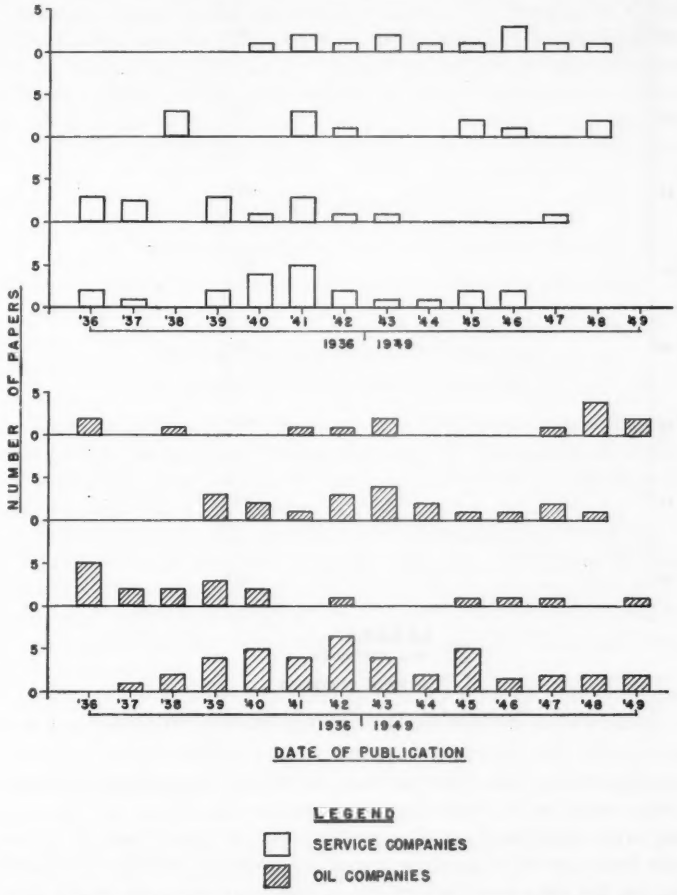


FIG. 2. Variation in the rate of publication by several companies from 1936–1949.

tributed to the two AAPG typical oil field volumes has suffered from such contribution. Geophysical Case Histories volumes should have a similar benefit, and no adverse effects." This quotation could be made to apply with a minimum of paraphrasing to other types of geophysical papers suitable for publication in *Geophysics*.

It is also hoped that in the future additional universities and pertinent government agencies

[1] Cortes, Henry C., "Publication of Geophysical Case Histories," *Geophysics*, 11 (1946), 287–291.

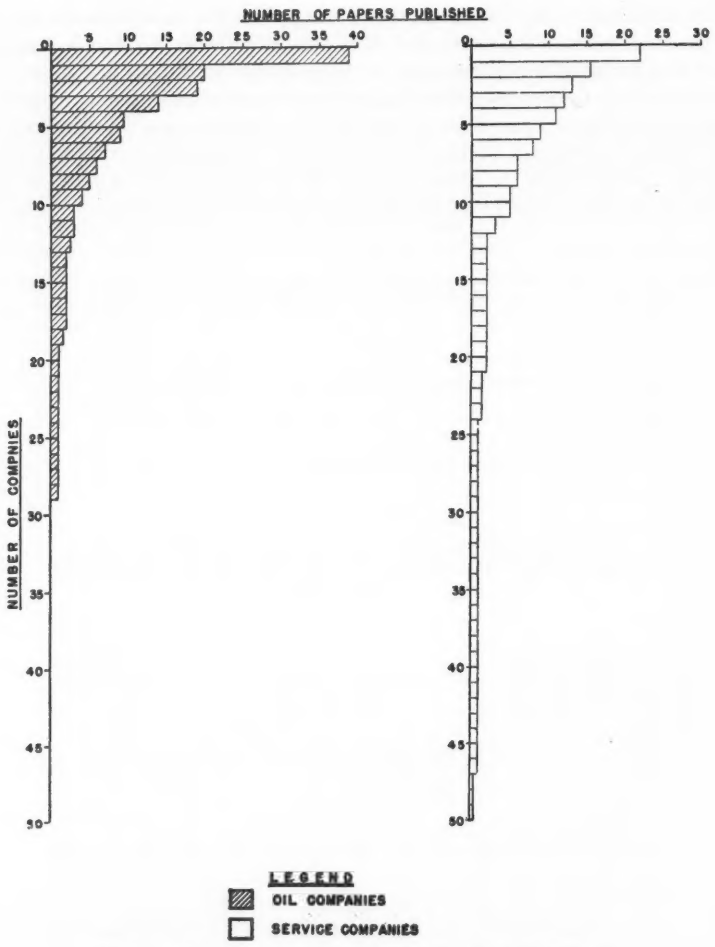

NUMBER OF PAPERS PUBLISHED
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30
NUMBER OF COMPNIES
0 5 10 15 20 25 30 35 40 45 50
LEGEND
OIL COMPANIES
SERVICE COMPANIES

FIG. 3. Number of papers printed by each contributor.

shall choose *Geophysics* more often than they have in the past as a publication medium for their research. This policy would help to make the subject matter of *Geophysics* more diversified and at the same time bring to the attention of practicing geophysicists the type of research in both pure and applied geophysics being conducted by these groups. It should be noted in this connection however that during the past few years contributions from at least one government agency have shown an appreciable increase and it is hoped that this trend will continue.

RICHARD A. GEYER
Editor

ABSTRACTS OF CERTAIN PAPERS PRESENTED AT THE GEOPHYSICAL CONFERENCE OF THE UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG, SOUTH AFRICA, HELD ON THE 27TH, 28TH, 29TH OF JULY, 1949

Pendulum Determinations of Gravity in South Africa

A. L. HALES AND D. I. GOUGH (*Bernard Price Institute*)

The Trigonometrical Survey Office, the Council for Scientific and Industrial Research and the Bernard Price Institute for Geophysical Research undertook in 1948 a gravimetric survey of Southern Africa, using pendulums loaned by the Department of Geodesy and Geophysics, University of Cambridge. In all, observations were made at 53 stations, the distance between stations being from 100 to 300 miles. Of these, two stations, those at the Trigonometrical Survey Office, Mowbray, and at the Bernard Price Institute, Johannesburg, were used as control stations, which were revisited on several occasions. The means at the control stations were 979.639 ± 0.0003 and $978.546_2 \pm 0.0003$ respectively. The distribution of the stations and the values of g at the stations are shown on a map.

A Gravimetric Map of the Union

J. F. ENSLIN AND B. D. MAREE (*Geological Survey*)

Plans to date are presented showing contours of gravity reduced by the Bouquer correction.

Meteorological Applications of Microseisms

W. SCHAEFFER (*University of Cape Town*)

Microseisms associated with ocean storms have been observed long before the swell produced by the storms has reached the nearest coast, showing that some microseisms are produced by storms over deep water. The most likely theory attributes this kind of microseism to standing waves formed by two trains of swell moving in opposite directions.

American workers used autographic records (with simultaneous time-marks) from three seismographs disposed in a triangle at distances of about two miles apart. The phase-differences allowed the speed and, particularly, the direction of arrival of waves, to be calculated. Two sets, each of three seismographs, were used to fix the positions of ocean storms. This technique would be particularly valuable in the Southern Hemisphere. The method is complicated by the arrival of microseims from different sources at the same time.

At the University of Cape Town a cathode ray oscilloscope has been used by the author to measure small phase differences, and to permit the use of seismographs at smaller distances apart. A tuned amplifier has been built (and is now being tested) to sort out waves of one frequency and so to deal with those from ocean storms alone.

Gravimeter Results in Prospecting for Witwatersrand Quartzites in the Transvaal and Orange Free State

O. WEISS (*Johannesburg*)

Gravimeter measurements have been used on a large scale in South Africa in search of Witwatersrand beds uder the cover of the Ventersdorp and Transvaal Systems. The discovery of the Orange Free State goldfields and the gold-bearing Upper Witwatersrand horizons on the farm Stilfontein, between Potchefstroom and Klerksdorp, was the result of mapping gravity anomlies with torsion balance and gravimeter. Gravimetric method is handicapped by acid Ventersdrop lavas and Ventersdorp sediments which have about the same density as the Witwatersrand quartzites, therefore areas of low gravity are not necessarily areas where Witwatersrand quartzites can be expected at shallow depth.

Development of Instruments For Radioactivity and Temperature Measurements in Narrow Boreholes

J. C. R. HEYDENRYCH (*National Physical Laboratory*)

The instruments for borehole logging consists of a temperature feeler unit, a radioactivity "pick-up" unit, a temperature indicator unit and a radioactivity indicator and recorder unit.

The temperature feeler unit is lowered down borehole on a rubber covered 0.036 inch diameter steel piano wire. A continuous signal is transmitted up the insulated steel wire, the frequency of the signal changing with the temperature of the feeler unit. At the top of the borehole a measurement of this frequency gives an indication of the temperature of the instrument of the borehole. In order to facilitate this measurement a frequency changing stage is used which reduces the frequency to a value that can be measured conveniently on a reed frequency meter.

The radioactivity "pick-up" unit transmits a continuous signal of constant frequency. This carrier frequency is modulated to zero by the pulses from a Geiger-Müller counter. At the surface this signal is amplified, detected, and the counts registered either on a conventional counter or on a counting rate meter. A recorder coupled to the winding gear enables continuous recording of radioactivity.

The outside diameter of all these units is 1.25 inches. The electronic design and operation of the instrument is discussed. Practical methods are developed for determining the probable error of the mean counting rate directly from the output records of the radioactivity receiver.

Temperature and Radioactivity Logging in Boreholes

D. J. SIMPSON AND F. R. BOUWER (*Geological Survey*)

Radioactivity and temperature measurements were carried out in a borehole on the farm Brakfontein 953, Harrismith district.

Temperature measurements showed a change of gradient at 1,500 feet corresponding to a change of formation from lower Beaufort to upper Ecca. A further change in gradient was observed on entering the Pre-Karroo formation at a depth of 4,510 feet.

The radioactivity traces indicated changes of radioactive normal, corresponding to different geological formations. The results indicate that radioactivity logging might be of use in correlation where radioactive markers are found.

Thermal Conductivity of Witwatersrand Rocks

M. A. COOPER (*Witwatersrand University*)

Data from measurements of thermal conductivity of core samples in boreholes on the Witwatersrand are presented. The measurements were made on samples from the same cores for which figures have been published previously—the samples being selected at closer intervals. The results are compared and collated with data from temperature measurements in the boreholes. The results are grouped according to characteristic geological features of the samples, deduced from petrographical examination of thin sections. The ratio of geothermic step to mean thermal conductivity, for different sections of the boreholes, is computed; this serves as a test of conditions of thermal equilibrium in the boreholes, and established the reliability of temperature measurements and geothermic step calculations.

Geophysical Survey of Tsumeb-West, South West Africa

N. LOWENSTEIN (*Johannesburg*)

As encouraging signs of mineralization were present round an aplitic intrusion similar to the Main Tsumeb ore body, a geophysical survey was carried out around the intrusion, consisting of gravimetric, self potential, resistivity, and magnetometric measurements.

A number of boreholes had been put down around the aplitic plug, and the gravimeter, self potential and resistivity measurements agree in showing the outlines of the aplitic intrusion and that no important ore deposits are present.

There were no magnetic anomalies.

Radar Observation of Thunderclouds

F. J. HEOITT (*Telecommunications Research Laboratory*)

Observation of precipitation by radar is discussed, including the theory of scattering, the effect of drop size and wavelength on echo power, and the choice of optimum wavelength in terms of radar performance.

Atmospheric attenuation due to oxygen water vapour and precipitation and the effect on the choice of wave length is considered.

The application of radar to the long-range detection of thunderstorms and the estimation of precipitation is discussed and the set developed by the Telecommunications Research Laboratory from a wartime airborne radar is described. The use of this set in the ASPIC experiments is mentioned. Some limited results of correlation with visual meteorological observations are included.

A film illustrating in a few minutes the development over a number of hours of precipitation in the vicinity of Johannesburg on typical summer afternoons was shown.

Tremor Seismology

P. G. GANE (*Bernard Price Institute*)

A review is given of the progress of experimental researches into the Witwatersrand Tremors, beginning with some statistical data derived from the material acquired before 1939 by the Union Observatory. The results of work done in 1939 using five mechanical seismographs are given, and the need explained for the more elaborate radio network at present in use. The organisation and equipment used for recent long range (400 km.) observation of tremors is described.

The Geographical Distribution of Some South African Earthquakes

W. S. FINSEN (*Union Observatory*)

A catalogue of 239 South African earthquakes is compiled, mostly from the files of the Union Observatory. The geographical distribution of 19 determined epicentres and 194 other shocks is shown on an accompanying map.

Recording Earth Tremors on Magnetic Tape

H. J. LOGIE (*Witwatersrand University*)

Inordinately large amounts of photographic paper are used if an attempt is made to combine the continuous photographic recording of seismic events with an open time-scale on the record. Equipment was built to overcome this difficulty.

Temporary records of tremors are very conveniently made by magnetizing a moving steep tape. Permanent photographic records may be obtained from this subsequently. It is thus not necessary to have the camera in continuous operation and the magnetic tape can be used over and over again.

A system involving a magnetic tape unit is described which automatically selects suitable tremors for permanent recording. The general design features of the trigger unit and the recording and reproducing mechanism are presented, together with the particular technique involved in recording low frequencies on magnetic tape by using a type of frequency modulation.

Crustal Structure in the Western Transvaal

A. L. HALES (*Bernard Price Institute*)

Dr. P. G. Gane has described the instrumental side of the programme of field seismic observations of the Witwatersrand earth-tremors carried out in the summer of 1948–1949 by members of the staff of the Bernard Price Institute and Mr. P. L. Willmore, guest researcher at the Institute. The travel time chart shown gives some of the results of that work. The phase normally designated *Pg Pn Sg* and

Sn were well observed. Travel time equations for these phases based upon an analysis of only part of the available data are as follows:

$Pg\ t=s/6.00+0.05\ s$ in kn. $Sg\ t=s/3.61+0.17$
$Pn\ t=s/8.35+7.86\ t$ in sec. $Sn\ t=s/4.84+13.59$

It is thought probable that the observations will support the existence of an intermediate layer but the analysis of the observations has not yet been carried to the stage at which this can be confirmed.

On the basis of a single crustal layer the thickness is determined as follows:—

From *P* 33.9 km. From *S* 36.7 km.

The Carnegie Institution Programme on Measurements of the Crustal Layers by Explosive Shots

H. E. Tatel and M. A. Tuve (*Carnegie Institution, Washington*)

Radio Communication Through Rock

T. L. Wadley (*Telecommunications Research Laboratory*)

Underground measurements of radio wave attenuation at varying frequencies in the Witwatersrand mines have been made and correlated with laboratory measurements on rock samples. These measurements indicate that communication over reasonable distances is only possible on low frequencies of the order of a few hundred kilocycles/sec. The extremely low efficiency of suitably small radiators at these low frequencies gives rise to an optimum frequency for particular circumstances which is a compromise between radiator efficiency and attenuation.

Theoretical and practical ranges of the order of 2,000 feet are obtained with full portable equipment and up to 6,000 feet with more bulky experimental equipment.

These results apply specifically to the type of rock encountered in the Witwatersrand's mines and are no indication of what might be possible in other underground workings elsewhere.

Determination of the Elastic Velocities in Borehole Cores

D. Simmons (*Bernard Price Institute*)

By putting cylinders (up to 50 cm. long) of rock into torsional and longitudinal oscillation, it is possible to determine the transverse and compressional wave velocities. Electromagnetic driving and pickup units, and an amplifier, were devised by means of which resonances in the oscillations were observed up to the 15th harmonic, involving frequencies up to about 40 kilocycles. The technique is described, and the transverse velocity in 18 samples of known rock types from various depths on the Witwatersrand is given.

Experimental Seismic Work in the Pienaars River and Vryburg Areas

J. C. Serfontein (*Geological Survey*)

Experimental refraction methods were employed to obtain the thickness of Karroo beds and the depth to the contact of the underlying granite on the farm Welverdiend near Pienaars River.

The method of fan-shooting proved to be successful in tracing dolerite dykes in the Karroo beds

The depth of decomposition in felsites occurring near the Rust-der-Winter dam, was probed by means of a series of short traverses.

In the Vryburg district it was possible to determine the thickness of Tertiary beds which overlies the Older Granite in the Pepani "laagte" and near Benesa.

It was possible to determine the thickness of the Ongeluk-lava near Heuningvlei.

Electrical Resistivity Measurements with Special Reference to Disturbing Factors

O. Weiss (*Johannesburg*)

Surface and near-surface heterogeneities cause well-known irregularities in resistivity measurements. While it can be assumed that sharp changes in the resistivity curves are caused by the surface

or near-surface variations in the resistivity, it is not easy to differentiate between the effects of shielding caused by the shallow, very good conductors and irregularities produced by patchy high and low resistance material at or near the surface. Examples are shown of shallow shielding effects produced by a very high conductor.

The Geomagnetic Elements in South Africa

A. M. VAN WIJK (*Hermanus Magnetic Observatory*)

In this paper an account is given of the known distribution of the magnetic elements in South Africa and of their secular changes, both past and present.

It is shown that in the secular variation field programme of the Hermanus Magnetic Observatory, exact re-occupation of the magnetic field stations is ensured. By determining not only the absolute value but also the diurnal variation of each element, representative values are obtained for the field stations. In order to eliminate as far as possible the effect of seasonal variations and of day-to-day changes in the elements, the values of the elements are expressed in the form of differences (Hermanus —Field Station). The field values are used in this form in calculating the secular variation.

This opportunity is taken of presenting the results of the magnetic survey carried out in 1947–48, a more detailed account of which is being published in pamphlet form by the Trigonometrical Survey Office. Projected improvements in the present scheme are discussed in the light of experience gained during the recent re-occupation of the secular variation field stations established in 1938–39. Appreciation is expressed of willing co-operation on the part of such of the neighbouring African territories as have thus far been approached with a view to participation in this scheme.

A Magnetic Map of the Union

J. F. ENSLIN AND B. D. MAREE (*Geological Survey*)

The Rate of Decrease of the Total Magnetic Vector with Height, as Observed by Aerial Magnetometer

O. WEISS AND H. FLETCHER (*Johannesburg*)

Examples are given of magnetic anomalies observed at different heights with the aerial magnetometer. The rate of decrease changes with the depth of the cause of the anomalies. The assumption that the change of magnetic anomalies with height can be calculated from a curve obtained at a single height, as claimed by some geophysicists, can be misleading if more than one magnetic horizon of different polarisation is involved in the measurements. For this reason it seems advisable that aerial magnetic traverses should be observed at different heights whenever depth calculations are attempted.

Measurements on the Residual Magnetisation of Ancient Sedimentary Rocks

JOHN W. GRAHAM (*Carnegie Institution, Washington*)

Geomagnetic Variation with Depth

D. I. GOUGH (*National Physical Laboratory*)

An account is given of measurements made by Dr Hales, of the Bernard Price Institute, Mr A. M. van Wijk, Officer-in-charge, Magnetic Observatory, Hermanus, and the writer. The variation of the horizontal and vertical components of the earth's magnetic field with depth were investigated by simultaneous readings at the surface and at depths of 4,000 to 5,000 feet below the surface in Blyvooruitzicht Gold Mine. Some theoretical difficulties in Blackett's hypothesis of the earth's field are discussed. The desirability of an accurate knowledge of the variation of the field with depth is emphasized It should be possible to find an effect due to mountains and Mr van Wijk was investigating some mountains in the Western Province with this object.

Reverse Magnetisation

O. WEISS (*Johannesburg*)

Examples of reverse magnetisation are given from observations of dykes and Lower Witwatersrand shales. It appears that large-scale reverse polarization of syenite dykes cannot be explained by stresses; yet, on the other hand, Lower Witwatersrand shales often appear to be polarized opposite to the present earth's field when subjected to intense faulting or stressing. It would be important to know whether the reverse polarization under high stresses is due to the mechanical or to the thermal conditions.

The Use of the Shoran System for Locating Aircraft Employed in Aerial Magnetometer Survey

H. FLETCHER (*Johannesburg*)

An airborne magnetic survey has clear advantages over ground work in both speed and extra data available for different heights. Furthermore, spurious local and unwanted surface geological effects are effectively eliminated and more objective results obtained. The full benefits of the above can only be reaped if the aerial recordings can be accurately related to the absolute ground position. In featureless country some form of radio position-fixing is imperative. The present paper seeks to give a broad outline of applicable navigational systems and in particular gives technical details of Shoran and its inherent suitability for survey purposes, mainly on account of direct visible indications to the pilot for arc flying and by automatic recording attachments. Shoran is eminently suited for straightforward additions and modifications, so that a system of actuating counters in an optical recording unit results in Shoran polar co-ordinates being photographed together with a vertical "shot" of the ground.

Statistical Weather Forecasting

T. E. W. SCHUMANN (*Meteorological Office, Pretoria*)

"Given a complete description of the state of the entire atmosphere at a given point of time, what will its condition be after a given interval of time?"

To this fundamental problem of the weather forecaster there are several lines of approach, one of which is the statistical method. In a paper entitled "An enquiry into the possibilities and limits of statistical forecasting" which appeared in 1944 the present author pointed out that this method had in the past been employed fairly extensively for long-range forecasting, with indifferent results, but that its methodical and systematic exploitation had never really been attempted, probably due to the vastness of such an undertaking.

In 1945 the Meteorological Research Bureau was established (recently incorporated with the Weather Bureau) and the Statistical Weather Forecasting Project was formally adopted as its main item of research. However, for several years the necessary personnel and calculating machines for carrying out the project were not provided, and accordingly very little progress could be made due to the fact that the method entails the computation of hundreds of thousands of correlation coefficients and cannot be successfully undertaken on a small scale. Preferably the field of investigation must cover the entire globe, but due to the non-existence of adequate data for the Southern Hemisphere, the investigation is at present being confined to the Northern Hemisphere.

Adequate personnel for carrying out the project was provided only in April, 1948, and at present there are some 25 persons (mostly temporary employees) engaged on the work. Difficulties in procuring an adequate outfit of punched-card machines were encountered. but these have been finally overcome during recent months, and satisfactory progress is now being made. However, due to the difficulties experienced in the development of the project, actual results are still very meagre, and some time must of necessity elapse before one will be able to judge the ultimate value of the investigation.

A Summary of Observed Magnetic Anomalies in the Union of South Africa

G. L. PAVER (*Johannesburg*)

Anomalous magnetic values are commonly encountered throughout the Union; their measurement and geological classification form the subject matter of this paper.

The measurements of magnetic variation have been made with vertical force variometers of the Lloyd-Schmidt type, with the observed values reduced to a selected base value, usually representing the normal values encountered over the Older Granite or Dolomite formations. The method of plotting is to show increases in the earth's magnetic field as positive anomalies.

Magnetic anomalies occurring in the Sedimentary systems have been investigated by traverses, sometimes of considerable length, across selected type sections. These measurements have resulted in the establishment of major magnetic anomalies, not only in the previously investigated Lower Witwatersrand System, but also in beds of the Kraaipan and Transvaal Systems.

The igneous rocks, plutonic hypabyssal, and extrusive, have been thoroughly investigated magnetometrically and the anomalous magnetic fields arising from their emplacement have been classified and summarized both geophysically and geologically.

Finally, the magnetic anomalies associated both directly and indirectly with ore occurrences have been investigated and the results are here described and discussed.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following candidates for membership in the Society. This publication does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualification of these nominees, he should send it to the president within thirty days. (Names of references appear in parenthesis after the name of each nominee.)

ACTIVE

Stanley Joseph Aszklar (Sigmund Hammer, P. F. Cerveny, W. B. Robinson)
Vernon Lee Brensing (R. L. Lay, B. H. Treybig, Jr., R. L. Galloway)
William Donald Dauphin (R. S. Jackson, C. H. Broussard, C. P. Harkins)
Frank Ellsworth (Henry Salvatori, Dean Walling, Harris Cox)
Gordon Russell Hess (C. E. Chesher, W. J. Tellington, H. M. Houghton)
John Robert Hill (R. W. Gemmer, P. L. Lyons, G. E. Wagoner)
John Wilson Lipscomb (Joe R. Wier—Associate Member, Bylaws Art. III, Sec. 2)
David Malmqvist (J. A. Sharpe, C. A. Heiland, Hans Lundberg)
Harry Bruce Mayo (Sidon Harris, P. H. Ledyard, R. H. Dana)
Harry Johnson McGrew (E. A. Eckhardt, Sigmund Hammer, L. J. Peters)
Anthony Edward Lloyd Morris (Robert Dyk, C. H. Johnson, N. R. Shade)
Irving John Reed (A. E. Storm, C. H. Green, H. B. Peacock)
William Reid Jr. (W. D. Mounce, J. E. LaRue, H. V. Goss)
Gaynor Orlando Rockwell (L. G. Howell, W. D. Mounce, C. L. Hubbard)
Gustav-Adolf Schulze (L. Mintrop, A. Schleusener, Bylaws Art. III, Sec. 2)
Sven Gustaf Törnqvist (Helmer Hedström, Allan Nordström,* Hans Hausen*)

ASSOCIATE

Donald Oliver Acrey (M. C. Kelsey, E. F. McMullin, J. F. Rollins)
Russell William Anderson (R. D. Everett, J. E. Bramlette, N. R. Park)

* Non-member reference accepted under Bylaws Art. III, Sec. 2.

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Robert W. Armstrong (C. H. Green, N. W. Mann, W. E. Dickson)
Roger Lasché Brown (J. B. Macelwane, Florence Robinson, F. Goldstone)
Francis John Campbell (A. A. Fitch, C. Twardowski, I. C. J. Bourne)
Kenneth Stanley Cressman (A. Gilmour, L. Y. Faust, H. M. Houghton)
Edwin A. Deupree (C. M. Ross, L. B. Trombla, R. M. Davis)
Ernst Robert Deutsch (T. Koulomzine, Leo Brossard, J. H. Hodgson)
James Edward Finley (A. W. Black, B. G. Swan, L. E. Whitehead)
Robert Dudley Fish (R. G. Elms, J. A. Moore, O. I. Jantz*)
Lloyd Philip Geldart (P. P. Gaby, C. H. Dix, B. Gutenberg)
Herschel Miller Glasgow (F. J. Agnich, Earl Thomas, G. J. Long)
John Milton Graves (F. B. Smith, R. A. Crain, J. R. Bradley, Jr.)
Wilbur Lawrence Harper (E. D. Gaby, A. G. Harvey, J. H. Todd)
Edwin Dana Hennessy (James Johnson, Richard Petersen,* John Rowley*)
Max Charles Jehan (E. van der Linden, A. A. Fitch, E. B. Lindsey)
Samuel Katz (Maurice Ewing, M. B. Dobrin, J. L. Worzel)
Charles Leslie Lake (C. K. Shepherd, B. G. Swan, L. E. Whitehead)
Lech Zygmunt Adam Makowiecki (A. A. Fitch, E. van der Linden, C. B. Twardowski)
John Charles Peffer (W. B. Roper, J. T. Geer, Evan Watts)
John T. Swearingin (C. K. Shepherd, B. G. Swan, L. E. Whitehead)
D. J. Van Nostrand (C. K. Shepherd, B. G. Swan, L. E. Whitehead)
Vernon Everett Whitney (R. C. Kendall, H. L. Thomsen, J. M. Nash)
David Ralph Williams (E. Van der Linden, A. A. Fitch, J. E. Woodburn)
Charles Lester Winn (C. J. Donnally, T. S. Napier, Richard Brewer)
Sherrill Ormond Woodall (C. H. Green, W. D. Coursey, K. E. Burg)
James Roddis Zivney, Jr. (Maynard P. Jones, J. W. Horn, R. W. Carson)

TRANSFER FROM ASSOCIATE TO ACTIVE

John A. Armstrong Joe. L. Ferguson Elliston B. Lindsey

TRANSFER FROM STUDENT TO ASSOCIATE

William W. Crump George D. Hobson Philip L. Lawrence
William J. Robinson John H. Wilson II

RESIGNATIONS

L. H. Inman H. S. Moore Morris Muskat
Louis C. Pakiser, Jr. M. A. Phillips
Constant Godefroy Malcolm H. Green William J. McElroy

MEETINGS OF THE LOCAL SECTIONS

ARK-LA-TEX GEOPHYSICAL SOCIETY

Shreveport

November 14, 1949

History of Upper and Lower Cretaceous Formations of the Ark-La-Tex Area, T. H. Philpott, The Carter Oil Company. (Abstract published in *Geophysics*, Vol. XV, No. 1—January, 1950—page 151)

FORT WORTH GEOPHYSICAL SOCIETY

October 31, 1949

Case History of the Compton Field, Stephens County, Texas, D. B. Campbell, Independent Exploration Co.

November 28, 1949

The regular meeting was held at the Texas Hotel, at noon. After discussion in both the Executive Meeting and before the society as a whole, it was decided to poll the members by mail as to their wishes in attempting to have the Fort Worth society be co-sponsor and host at the next regional meeting planned for 1950.

Ray W. Dudley reported on the present status of the public relations project.

Movies of the TCU–Texas football game were presented and Mr. Clark of the TCU coaching staff made a few brief comments.

R. H. Dana,
Secretary-Treasurer

PACIFIC COAST SECTION
SOCIETY OF EXPLORATION GEOPHYSICISTS

November 17–18, 1949—Annual Fall Meeting

The following is a very brief description of the annual fall meeting of the Pacific Coast Section of the Society of Exploration Geophysicists. Membership in our section on the coast has grown quite rapidly and capacity attendance was enjoyed during the presentation of all the papers.

The annual fall joint society meeting was held at the Ambassador Hotel, Los Angeles, California. A series of geophysical papers were presented during the morning of November 21, and one paper on offshore seismic problems was given at the afternoon joint session with the AAPG.

C. Hewitt Dix, Chairman of the Program Committee, and Robert C. Dunlap, President of the Pacific Coast Section, were co-chairmen of the meeting. (Abstracts of the papers appear in *Geophysics*, Vol. XV, No. 1—January, 1950—page 155).

On Friday, November 18, a luncheon and concluding session of the S.E.G. was held at the Mona Lisa Restaurant. The interesting subject, "Direction of Fault Movements in Southern California as Indicated by Seismograms of Earthquakes," was discussed by Beno Gutenberg and Peter Dehlinger of California Institute of Technology. John Sloat, Chairman of the Tellers Committee, announced the election of officers for the coming year as follows:

President: R. A. Peterson, United Geophysical Company, Pasadena, Calif.

Vice President Northern District: T. P. Ellsworth, Richfield Oil Co., Bakersfield, Calif.

Vice President Southern District: E. L. Erickson, Continental Oil Co., Los Angeles, Calif.

Secretary-Treasurer: D. H. Scott, The Texas Co., Bakersfield, Calif.

D. H. Scott
Secretary-Treasurer

Bakersfield, November 22, 1949

GEOPHYSICAL SOCIETY OF TULSA

December 8, 1949

A Single Boat Seismograph System, L. C. Paslay, Marine Instrument Company. (Abstract appears in *Geophysics*, Vol. XV, No. 1—January, 1950—page 152). Mr. Paslay described, with the aid of slides and colored movies, equipment and methods of operation in the Gulf of Mexico.

Reflection Shooting in the North Snyder Area, Scurry County, Texas, Neal Clayton, Republic Exploration Company. (Abstract appears in Geophysics, Vol. XV, No. 1—January, 1950—page 154). Specimen records were introduced to show that at least in certain parts of the area, a reflection is obtained from the top of the reef.

N. R. Sparks
Secretary-Treasurer

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COLORADO SCHOOL OF MINES
SOCIETY OF STUDENT GEOPHYSICISTS

September 16, 1949

The meeting, held in the Geophysics Library, was called to order by Vice President Howard W. Leaf, who explained that the purpose of this meeting was a drive for new members, and acquaintance of all members with the activities the society plans to carry out during the 75th Anniversary of the Colorado School of Mines. It was stated that the society would display the Standard Oil of New Jersey art exhibit and hold a luncheon at the Holland House on Friday, September 30, 1949.

Publicity, membership, and entertainment committees were appointed. They are as follows:

Publicity—Clyde Kernes and Robert W. Meader

Membership—C. W. Bowlby and Hugh W. Olmstead

Program and Entertainment—F. Endacott, Richard Miller, E. V. Dedman and William H. Throop.

Applications for membership were received from thirty-seven students at this meeting, which was attended by fifty members and guests.

September 22, 1949

At this meeting, held in the Geophysics Library, detailed plans for the luncheon were made. Twelve applicants for membership were elected with those who applied at the previous meeting. 1949–1950 membership dues were paid by sixty-seven members.

September 30, 1949

A luncheon was held at the Holland House at 12:30 on September 30th, with one hundred members and guests attending.

Vice President Howard Leaf introduced Mr. Ralph Holmer, who in turn introduced the following guests to the members.

D. H. Clewell	E. A. Eckhardt	Sigmund Hammer
C. A. Heiland	Cecil H. Green	R. Clare Coffin
Hans Lundberg	J. M. Hollister	

The meeting was then turned back to Vice President Leaf, who introduced W. H. Courtier, of Phillips Petroleum Company. Mr. Courtier gave an interesting talk entitled "The Humorous Side of Geophysics in the Field." The luncheon adjourned at 1:45 in order for members and guests to attend sessions of the 75th Anniversary.

An exhibition of documentary paintings from the collection of Standard Oil Company (N. J.) was loaned us for use during the anniversary celebration. Famous artists such as Peter Hurd and Thomas Benton covered the oil industry in all its phases. Their oil paintings and water colors were of great interest to all eight hundred who attended.

October 19, 1949

The meeting, called to order by Vice President Leaf, was held in the Geophysics Wing. Norman Domenico showed slides and gave an interesting report on his expedition to Alaska. The slides included operation of a seismograph mounted on a sled at the Seward ice field near Mt. St. Alliance.

W. J. BUSTEED
Secretary-Treasurer

THE UNIVERSITY OF TULSA STUDENT GEOPHYSICAL SOCIETY

The activities of the student section at The University of Tulsa during November and December, 1949, were as follows:

MEMBERS OF THE UNIVERSITY OF TULSA STUDENT GEOPHYSICAL SOCIETY

Front row (left to right): V. L. Jones (Faculty Sponsor), C. D. Lewis, J. B. Etnyre (President), H. Hobart, Jr., Tom Teegarden, Don Standley. *Second row:* Edgar Ragan, Howard Flemming, W. D. Strait, Jack Kimball, L. M. Holley. *Third row:* Simha Golosovker, B. G. Preston, Chet H. Jameson, Jr., Sam Cooke, Lee Price, Richard Beightol. *Fourth row:* Milton Lea, Francis O'Brien.

November 9, 1949

Mr. R. Clare Coffin, Geophysical Coordinator, Stanolind Oil & Gas Co., spoke on "Geophysical Imagination in the Interpretation of Geophysical Data." Mr. Coffin showed slides and discussed the history of discovery and development of several oil fields.

November 17–18, 1949

Seven senior members of the society attended the regional meeting of S.E.G. in Dallas. While in Dallas they were conducted by Mr. W. D. Coursey on a tour of the Geophysical Service Inc. Laboratories.

December 3, 1949

Henry Hobart, Jr., senior at the university, presented a paper before the Oklahoma Academy of Science at Enid, entitled "Magnetic and Gravitational Corelation in the Owasso Dome Area." This paper consisted of a progress report of the Geophysics 70 and 80 classes laboratory projects under the direction of Professor V. L. Jones. Magnetic and gravitational maps and profiles were shown together with structural maps obtained from well log data.

UNIVERSITY OF MICHIGAN LIBRARIES

December 13, 1949

Mr. Robert Blaisdell, Personnel Manager for Seismograph Service Corporation, discussed present domestic and foreign seismic operations with emphasis on training programs, living conditions and employee welfare.

JOHN B. ETNYRE
President

ANNOUNCEMENTS

PERMIAN BASIN GEOPHYSICAL SOCIETY ORGANIZES

A meeting of the newly organized Permian Basin Geophysical Society was held Tuesday evening, December 20, 1949, at 8 P.M. in the District Courtroom at Midland, Texas.

Officers elected for 1950 were: Lorenz Shock, National Geophysical Company, president; C. W. Payne, Pure Oil Company, first vice president; J. B. Worley, Strawn Merchandise Co., second vice president; W. L. Homan, Republic Exploration Co., secretary; and E. L. Mount, Continental Oil Co., Treasurer. The meeting was attended by forty-five members.

Plans are under way to request affiliation with the Society of Exploration Geophysicists. (Request by petition received by S.E.G. January 20, 1950.)

W. L. HOMAN
Secretary

BOOKS OF INTEREST TO GEOPHYSICISTS

Beginning with the January, 1950 issue of *Geophysics*, a new service for members of the S.E.G. was initiated by the Business Office. In each issue of the Journal will be found advertisements of certain books on subjects related to geophysics, which can be purchased through the Business Office of the society. In return for placing the advertisement the society is granted a commission on all sales. Every attempt will be made to list the most recent publications. Members of the society are urged to take advantage of this service. See page 302 for list.

HIGHWAY RESEARCH BOARD

The twenty-ninth annual meeting of the Highway Research Board was held on December 13–16, 1949 at the National Research Council. Papers of geological interest presented at the meeting included:

"Influence of Topographic Position in Airphoto Identification of Permafrost," R. E. Frost and Olin Mintzer.

"Development of Geophysical Methods of Subsurface Exploration in the Field of Highway Construction," R. W. Moore.

"Maps for Construction Materials," Frank Byrne.

"Drainage Pattern Significance in Airphoto Identification of Soils and Bedrock," Merle Parvis.

"Some Capillary Phenomena in Sandy Materials," D. P. Krynine.

"Modification of Gumbotil Soil by Lime and Portland Cement Admixtures," M. G. Spangler and O. H. Patel.

"Some Chemical, Physical and Mineralogical Features of Soil Colloids," J. H. Havens, J. L. Young, Jr. and W. B. Drake.

Synopses of these papers, and others presented at the meeting, are contained in the H.R.B. *Abstracts* for December, 1949, price 30¢.

The H.R.B. has also issued two Bulletins useful to engineering geologists. These are:

"The Appraisal of Terrain Conditions for Highway Engineering Purposes," Bulletin 13, November 1948, 90 pages, price $1.50.

"Engineering Use of Agricultural Soil Maps," Bulletin 22, October 1949, 128 pages, price $1.80.

Publications and further information may be secured by writing to R. W. Crum, Director, Highway Research Board, 2101 Constitution Ave., Washington 25, D. C.

PERSONAL ITEMS

Members of the society are invited to submit notices of changes in position and address for publication in this department. Public relations departments of companies are requested to place *Geophysics* on their mailing lists to receive releases concerning employees engaged in geophysical work. Information should be addressed to *Geophysics*, Box 1614, Tulsa 1, Oklahoma.

LORENZ SHOCK, party chief for the National Geophysical Company, Dallas, has been elected president of the Permian Basin Geophysical Society. Shock, a graduate of the University of Oklahoma, is a member of Sigma Xi, Phi Beta Kappa, American Association of Petroleum Geologists and Society of Exploration Geophysicists.

LIEUTENANT COLONEL MERLE C. BOWSKY is now Assistant Commandant of the Signal School, Fort Monmouth, New Jersey, and his home address is 28 Carty Avenue, Fort Monmouth, N. J.

RICHARD L. FENTEM is now chief computer for Amerada Petroleum Corp., Box 2040, Tulsa 2, Oklahoma.

J. E. BARTHELEMY, JR. received the degree of Bachelor of Science in Petroleum Geophysics from the Institute of Technology, St. Louis University, on June 7, 1949. One week later (June 13th) he rejoined Western Geophysical Company International at Lac la Biche, Alta., Canada, and within two weeks (July 1st) he became party chief of Party F-53. Mr. Barthelemy has transferred from Student to Associate membership in the Society.

DAVID F. COOLBAUGH has become geologist for Anaconda Copper Mining Company, Darwin California.

R. J. COPELAND is Assistant Supervisor of Geophysics, Canadian Gulf Oil Co., Calgary, Alta., Canada.

CHESTER J. DONNALLY, Dallas, Texas, Supervisor for Western Geophysical Co., has been conducting a one-man membership drive for the S.E.G. since completing his job as advertising manager for the Dallas Regional Meeting. He has distributed about one hundred application forms to Western Geophysical Co. crews; the results of this campaign will appear in the "Round Table" of the July issue.

INCIDENTALLY—the Business Office has just obtained a large number of application forms. There is no charge for these forms. Members may obtain any number by writing to the Business Office, Box 1614, Tulsa 1, Oklahoma.

MARY JO CLARK, Humble Oil & Refining Co., Houston, is spending much of her time acting as Assistant to Editor. Her duties include proof-reading, and the handling of much of the Editor's correspondence with contributors to *Geophysics*.

BEN S. MELTON now gives his business address as Hq USAF, DCS/O, (AFOAT-1). His home is at 10112 Pierce Drive, Silver Spring, Md.

H. K. HERR is seismic party chief for Kerr-McGee Oil Industries, Inc., Oklahoma City, and is now in the field at 118 Third St., McComb, Mississippi.

T. A. HALBROOK is supervisor for Geophysical Service Inc. at 510 9th Ave. West, Calgary, Alta., Canada.

RALPH C. HOLMER, faculty adviser of the Colorado School of Mines Society of Student Geophysicists, reports that senior sudents who are members of the society plan to attend the annual meeting in Chicago. A large group travelled from Golden to St. Louis by bus to attend the 1949 annual meeting.

JAMES D. KEESE has advanced from assistant computer to computer for The Texas Company, Box 759, Port Arthur, Texas.

HAROLD MOONEY, who recently completed graduate work at California Institute of Technology, has accepted a position on the faculty of the University of Minnesota. He will teach courses in geophysics.

DR. A. VAN WEELDEN, Chief Geophysicist for Bataafsche Petroleum Mij. in The Hague, Holland, will carry the standard of SEG at the International Petroleum Congress to be held at The Hague next year. Dr. van Weelden hopes to interest European Geophysicists in organizing a European section of the SEG.

B. O. WINKLER is Chief Geophysicist for Standard-Vacuum Oil Company, 26 Broadway, Room 1564, New York 4, N. Y.

GEORGE SHOR, JR. is now party chief for Seismic Explorations, Inc., Houston. He is in the field at Box 8, Lovington, New Mexico.

WILLIAM KERR RANKIN, a recent graduate of The University of Toronto, has accepted a position with Bataafsche Petroleum Mij., and is receiving a special training course in oil geology at the company's headquarters in The Hague.

IRVING M. GRIFFIN, JR. formerly with General Geophysical Company as seismic supervisor of the Pacific Coast and Rocky Mountain divisions, has opened an office for seismic consulting at 1331 Esperson Building, Houston 2, Texas.

FRANK B. JOHNSON died of leukemia in Herman Hospital, Houston, on September 29, 1949. Frank was aware of his condition for almost two years yet remained active in his work until just two weeks prior to his passing. His courage in the face of insurmountable odds was of no surprise to those who knew him well, yet he will always be remembered for his wonderful fighting spirit.

Frank was born in Austin, Texas, on February 7, 1915. He attended elementary and high school in Austin and obtained his Bachelor of Arts degree in Physics at the University of Texas in 1937. Upon graduation, he secured employment with the Humble Oil & Refining Company in Houston. He worked with the geophysical department until 1942 when he was granted special leave of absence to do research work with the Naval Ordnance Laboratory in Washington, D. C., and Solomons, Maryland, his work there being both technical and supervisory in the Testing Department.

He was married to the former Wilma Chrisman on January 25, 1941. They resided at 1625 Colquitt.

In November of 1945 he returned to Humble and assumed an important role in the design and development of geophysical equipment to be used by the Company in the exploration of the continental shelf.

Frank's untimely death is regretted by his friends in the Society and our utmost sympathy is extended to his wife and family.

HORACE T. MASTERSON

M. P. JONES has resigned his position as president of Geotechnical Exploration Corporation to establish his office as a consulting geophysicist at 3552 Rankin, Dallas, Texas. He is engaging in various phases of geophysical work, primarily in review interpretation of seismic data and in consultation and supervision of current exploration programs.

WALTER J. OSTERHOUDT is now associated with Geophysical Service Inc. and is in charge of their Houston office at 1416 Esperson Building. He had previously resigned his position with the Houston division of the Gulf Oil Companies as supervisor of the Gulf Research and Development Company's seismograph operations, in the spring of 1949, and had spent several months on his ranch in southwestern Colorado enjoying the wide open spaces, before joining GSI. Mr. Osterhoudt had been associated with Gulf since 1930 and was active in the development of that company's seismograph operations in the Gulf Coast, Oklahoma, California, Mexico and Venezuela.

G. J. (JACK) KOHLER, JR., South Mexico supervisor for Geophysical Service Inc., has moved to New Orleans, 6543 Vicksburg Street, and has been made supervisor of GSI operations in South Louisiana. VIRGIL W. TEUFEL, formerly in charge of the Houma office, has moved to Shreveport, where he will supervise GSI operations in Mississippi, North Louisaina and South Arkansas. He is in charge of the Shreveport office. CHRIS H. ELSTON will continue in charge of the Houma shop and will assist in special problems pertaining to field equipment and operating techniques.

R. K. CARTER, formerly president of Advanced Exploration Company, is now with Standard Oil of Texas, Box 1660, Midland.

FRANK ITTNER recently was named vice president of The Superior Oil Company. He will remain in Los Angeles as manager of the company's exploration department for the Pacific division.

THOMAS R. SHUGART, formerly vice president of Geotechnical Service Corp., has announced the opening of his offices to serve as geophysical consultant, specializing in seismic interpretations and in seismic supervision. His offices, which opened in February of this year, are located at 1520 Mercantile Securities Building, Dallas, Texas.

ARCHIBALD G. EBERTS, a research computer in the Seismograph Department of the Sun Oil Company, died at Beaumont, Texas, on January 28, 1950, after an illness of almost two months.

Before joining Sun in November 1947, Mr. Eberts had worked with The Texas Company from 1934 to early 1947, and had engaged in private engineering work from that time until joining Sun.

Mr. Eberts was born October 7, 1910, at Litchfield, Minnesota. He attended the University of Utah for one year and received a B.S. degree in engineering from Clarkson College of Technology at Potsdam, New York in 1934. He was a member of the Texas Society of Professional Engineers and of the Society of Exploration Geophysicists.

He is survived by his wife, a son, his father, one brother and one sister.

L. G. ELLIS

SOCIETY OF EXPLORATION GEOPHYSICISTS

CONSTITUTION

Article I.	Name	Article X.	Meetings
Article II.	Object	Article XI.	Local Sections
Article III.	Membership	Article XII.	Districts
Article IV.	Code of Ethics	Article XIII.	Affiliated Societies
Article V.	Election, et cetera, of Members	Article XIV.	Committees
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Article VII.	Duties of Officers	Article XVI.	Review by Members
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CONSTITUTION

(As amended to August 26, 1948)

Article I. Name

Section 1. The Society shall be called the "Society of Exploration Geophysicists."

Article II. Object

Section 1. The objects of this Society shall be to promote the science of geophysics especially as it relates to exploration and research, to foster the common scientific interests of geophysicists, and to maintain a high professional standing among its members.

Article III. Membership

Section 1. The membership of this Society shall consist of persons elected and qualified in accordance with the Constitution and Bylaws of this Society at the time of such election.

Section 2. The membership of this Society shall consist of Honorary Members, Active Members, Associate Members, and Student Members.

Section 3. To be eligible to election to Honorary Membership a person shall, in the unanimous opinion of the Standing Committee on Honors and Awards and the Council, have made a distinguished contribution to geophysics or a related field which warrants exceptional recognition.

Section 4. To be eligible to election to Active Membership an applicant must have been actively engaged in practising or teaching geophysics or a related field for not less than eight years (up to four years as a student in a recognized college or university may be counted toward this total) of which at least three years must have involved work of a responsible nature calling for independent judgment and the application of geophysical or geological principles.

Section 5. To be eligible to election to Associate Membership, an applicant must be actively interested in geophysics.

Section 6. To be eligible to election to Student Membership an applicant must be a graduate or undergraduate student in good standing in residence at a recognized university or college.

Section 7. An Honorary Member or Active Member shall enjoy all privileges of the Society. He shall be eligible to hold any office, to vote on all matters submitted to the membership, to petition the Council or Executive Committee on any matter, to sponsor applicants for membership and to publish his affiliation with the Society.

Section 8. An Associate Member or Student Member shall be entitled to attend the meetings of the Society, to receive its Journal and to purchase its publications, on the same terms as an Active Member. He shall have none of the other privileges of membership and in publishing his affiliation with the Society shall clearly indicate his grade of membership.

Article IV. Code of Ethics

Section 1. Membership of any class shall be contingent upon conformance with the established principles of professional ethics.

Article V. Election, Resignation and Expulsion of Members

Section 1. The method of election to the various grades of membership shall be as set forth in the Bylaws.

Section 2. Any member in good standing may resign from the Society at any time as set forth in the Bylaws.

Section 3. Any member may for the good of the Society be suspended or expelled from the Society at any time as set forth in the Bylaws.

Article VI. Officers

Section 1. The officers of the Society shall be a President, a Vice-President a Secretary-Treasurer, and an Editor. Officers shall be elected in the manner prescribed in the Bylaws for a term of one year with the exception of the Editor, whose term shall be two years.

Section 2. Election of officers shall be by secret mail ballot. On the ballot shall be printed the nominees for each office arranged in alphabetical order.

Section 3. The Standing Committee on Nominations shall nominate, in the manner prescribed in the Bylaws, two candidates for each office to be filled. Further nominations may be made by petition as set forth in the Bylaws.

Section 4. The officers shall assume the duties of their respective offices immediately after the close of the Annual Meeting following their election.

Section 5. No officer shall be eligible for election to the same office for two consecutive terms.

Section 6. In case of a vacancy in any office, other than the President's, the Executive Committee shall select a successor to serve until the close of the annual meeting following this appointment.

Article VII. Duties of Officers

Section 1. The President shall be the presiding officer at all the meetings of the Society, shall take cognizance of the acts of the Society and of its officers, shall appoint such Standing Committees and special committees as are required for the purposes of the Society, and shall delegate members to represent the Society. He may, at his option, serve on, and may be chairman of, any committee. He shall prepare an address to be given before the members of the Society at the Annual Meeting.

Section 2. The Vice-President shall assume the office of President in case of a vacancy from any cause in that office and shall assume the duties of President in case of the absence or disability of the latter. He shall also be responsible for all National Meetings of the Society.

Section 3. The Secretary-Treasurer shall assume the duties of the President in case of the absence of both the President and Vice-President. He shall have charge of the financial affairs of the Society and shall annually submit reports as Secretary-Treasurer covering the fiscal year, which he shall arrange to have published in the next regular issue of the Journal of the Society. Under the direction of the Council, he shall arrange for the receipt and disbursal of all Society funds. He shall cause an audit to be prepared annually by a public accountant at the expense of the Society. He shall give a bond, and shall cause to be bonded, all employees to whom authority may be delegated to handle Society funds. The amount of such bonds shall be set by the Council and the expense shall be borne by the Society.

Section 4. The Editor shall be in charge of the editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the regular Society publication and for special publications, and may accept or reject material offered for publication. He may appoint associate, regional, and special editors.

Article VIII. Council

Section 1. The Council of the Society shall consist of the officers, the Past President, the Past Prior President, and all elected District Representatives.

Section 2. The Council shall be the governing body of the Society and subject to the provisions of the Constitution and Bylaws shall have full control and management of the affairs and funds of the Society.

Section 3. A joint meeting of the outgoing and incoming Councils shall be held at the call and under the Chairmanship of the newly elected President during or within seven days after the Annual Meeting of the Society. At this joint meeting the Councils shall hear reports from all Officers and Committees and review the activities of the Society for the past year. With the advice of the outgoing Council, the incoming Council shall conduct any necessary business and issue instructions or recommendations to any officer or committee, subject to the provisions of the Constitution and Bylaws. All committee chairmen shall attend this meeting, but, as Chairmen, shall have no vote.

Section 4. At the call of the President or a majority of the Council members, and after written notice to all Council members, the Council may meet at any time.

Section 5. A quorum at any meeting of the Council shall consist of six Council members.

Section 6. Unless otherwise provided by the Constitution, all actions by the Council shall require a majority vote of the members present.

Article IX. Executive Committee

Section 1. The Executive Committee shall consist of the President, the Vice-President, the Secretary-Treasurer, the Editor, and the Past President.

Section 2. When the Council is not in session the Executive Committee shall have full authority, subject only to prior instructions by the Council, to exercise all powers of the Council.

Section 3. All actions of the Executive Committee shall require a majority vote of all members of the Committee.

Section 4. The Executive Committee may vote on any matter either by mail or in person.

Article X. Meetings

Section 1. The Society shall hold at least one meeting of the members each year, this meeting to be known as the Annual Meeting. One session of this meeting shall be a Business Meeting, at which reports of the Officers and Committees shall be read and the result of the mail ballot for officers announced.

Section 2. The Annual Meeting shall be held at a time and place designated by the Executive Committee.

Section 3. Additional meetings of the Society may be called by the Executive Committee.

Article XI. Local Sections

Section 1. Local sections, consisting of members of the Society and other persons engaged in geophysics or a related field residing within an appropriate distance of a central point, may be organized as provided in the Bylaws.

Section 2. Each local section shall assist in carrying out the objectives of the Society within the territory assigned to the section by the Council.

Section 3. Each local section shall have one district representative if among its members there are less than seventy-five Honorary Members and Active members of the Society in good standing, two district representatives if more than seventy-five and less than one hundred fifty, or three district representatives if more than one hundred fifty.

Section 4. The district representatives shall be elected from among the Honorary Members and Active Members of the Society in good standing for terms stated and in the manner prescribed in the Bylaws and shall not be eligible for two consecutive terms.

Article XII. Districts

Section 1. The Council shall divide the area of the continental United States, not assigned to local sections, into not more than seven districts. Council may designate districts outside the area of the continental United States.

Section 2. Each district shall have for each seventy-five Active members of the Society, who are not members of a local section, one district representative, who shall be appointed by the President, for a term of one year expiring at the close of the Annual Meeting.

Article XIII. Affiliated Societies

Section 1. The Council may arrange for affiliation of the Society with any duly organized groups or societies.

Section 2. The terms of affiliation must provide that the Society shall have the right to dissolve such affiliation at any time, subject only to the payment of any sums it may legally owe the affiliated group or society.

Article XIV. Committees

Section 1. In addition to the Executive Committee, there shall be appointed Standing Committees to further the purposes of the Society.

Section 2. The duties of the Standing Committees and the method of their appointment shall be in accordance with the Bylaws.

Section 3. The President may at any time appoint Special Committees for such purposes as he may deem fit.

Section 4. The terms of all Special Committees shall expire at the close of the Annual Meeting following their appointment.

Article XV. Business Manager

Section 1. The Council may employ a Business Manager for the Society and pay him such salary and other compensations from the Society's funds as they deem advisable.

Section 2. The Business Manager shall provide a bond appropriate in amount, the cost to be borne by the Society.

Section 3. The Business Manager shall, under the supervision of the Secretary-Treasurer, perform such duties as the Council may assign him.

Section 4. The Council may discharge the Business Manager at any time.

Article XVI. Review by Members

Section 1. All acts of the Officers, Council, and Committees of the Society shall be subject to review by the members.

Section 2. Proposals to change any decision, policy or procedure of any Officer, the Council, or any Committee shall be submitted in writing to the President and signed by at least twenty-five Honorary and Active Members in good standing.

Section 3. Upon receipt of such a petition with a sufficient number of valid signatures, the President shall advise the Council and the Officer or Committee involved.

Section 4. Should the Officer or Committee involved be unwilling to comply with the petition, it, together with a discussion by the proposer and the Officer or Committee involved, shall be published in the next issue of the Society's Journal.

Section 5. Within thirty days after publication in the Journal, the petition shall be submitted to the membership by mail ballot by the President. A majority of the ballots returned within thirty days after being mailed by the President shall be decisive. Should the vote favor the petition, it shall be complied with, within the limitations imposed by the Constitution and Bylaws, as promptly as practicable.

Article XVII. Bylaws

Section 1. The Council shall make such Bylaws not in conflict with the Constitution, as it may deem necessary for the proper government of the Society. The Council may amend the Bylaws at the annual joint meeting by an affirmative vote of two-thirds of the members of the incoming Council present. All proposed amendments must, however, be published in the Society's Journal before being submitted to the Council.

Article XVIII. Amendments to the Constitution

Section 1. Amendments to this Constitution may be proposed by any ten members of the Society, by any Officer of the Society, or by a Constitutional Committee appointed by the President.

Section 2. Any proposed amendment shall be submitted to the President in time for publication in the Society's Journal prior to the Annual Meeting.

Section 3. At the annual joint meeting of the Council, all proposed amendments received since the previous annual meeting, shall be considered. Those receiving approval from a majority of the members of the incoming Council present shall be submitted by mail ballot, arranged by the Secretary-Treasurer, to the entire membership of the Society within sixty days. If a majority of the ballots returned within sixty days of their mailing favor the proposed amendment, it shall become effective at the expiration of this sixty days. All amendments shall be reported in the Society's Journal.

BYLAWS

Article I. Publications
Article II. Election of Honorary Members
Article III. Election of Active, Associate and Student Members
Article IV. Dues
Article V. Resignation of Members
Article VI. Expulsion of Members
Article VII. Election of Officers
Article VIII. Local Sections
Article IX. Finances of Local Sections
Article X. Standing Committees

BYLAWS

Article I. Publications

Section 1. The Society shall publish a Journal entitled *Geophysics*.

Section 2. The Journal shall be published at intervals designated by the Executive Committee.

Section 3. All reports to the Society by its officers and committees shall be published in the Journal. All members of the Society shall be presumed to have due notice of all Society matters published in the Journal. Each issue shall contain a membership list of all Standing and Special Committees.

Section 4. Original papers, reviews, abstracts, notes or letters containing information deemed by the Editor to be of interest to the members of the Society shall be published in the Journal. The Editor shall be the sole judge of whether such material is to be published.

Section 5. The subscription rate of the Journal shall be $6.00 ($6.50 foreign) per year to nonmembers and $3.00 per year to members. The first $3.00 of the annual dues of each due paying member shall be set aside for the payment of his subscription to the Journal. Members of affiliated Societies shall be entitled to receive the Journal upon payment of a fee equivalent to the dues charged to an associate member.

Section 6. The Council may at its annual joint meeting authorize the printing of special publications to be financed and distributed in a manner approved by the Council.

Article II. Election of Honorary Members

Section 1. The Standing Committee on Honors and Awards may submit to the President ninety days before the Annual Meeting the names of any person or persons they deem eligible to election as an Honorary Member. Their report shall explain the basis of their recommendation.

SECTION 2. The President shall submit copies of any such reports to all members of the Council not less than sixty days before the Annual Meeting.

SECTION 3. The Council members shall consider all such reports and vote by mail thirty days before the Annual Meeting. Unanimous action by those voting shall be required to elect any person as an Honorary Member.

ARTICLE III. ELECTION TO ACTIVE, ASSOCIATE AND STUDENT MEMBERSHIP

SECTION 1. An applicant for election to Active, Associate or Student Membership shall submit to the Business Manager of the Society an application setting forth in detail his education and experience. The application shall list the names and present addresses of persons who can verify the statements given therein. It shall list not less than three Active Members or Honorary Members of the Society, in good standing, who are personally acquainted with the training or experience of the applicant. This application shall be open to inspection at any time.

SECTION 2. The Executive Committee may waive the requirement of references from members of the Society for geographical or other reasons, if the applicant is otherwise eligible and furnishes other satisfactory references.

SECTION 3. The Business Manager shall write to all references for verification of the applicant's statements. All replies from references shall be considered confidential and shall not be disclosed except to the Executive Committee, without the references' prior written consent.

SECTION 4. The Business Manager, upon receipt of the replies from all references, shall submit to the Executive Committee the application and the replies from the references.

SECTION 5. Should the Executive Committee unanimously approve and sign the application, the applicant's name shall be published in the next regular issue of the Society's Journal for approval by the membership at large. If no objection to his election is received by the President within thirty days after this publication, he shall be pronounced elected. The Business Manager will notify the applicant. In the case of applicants for Student Membership publication is not required. The student member shall be pronounced elected when approved by the Secretary-Treasurer.

SECTION 6. An applicant for membership, upon being notified in writing of his election, shall pay full dues for the current year and upon making payment shall receive a membership card and the regular Society publications for the year of entrance. Unless payment of dues is made within thirty days by those living within the continental United States and within ninety days by those living elsewhere, the Executive Committee may rescind the election of the applicant.

SECTION 7. An Associate or Student Member may seek transfer to Active Membership by supplying added information to show that he has become eligible to election to Active Membership. The transfer shall be handled in the same manner as election to Active Membership. The Standing Committee on Membership may of its own initiative secure the necessary added information and submit it to the Executive Committee.

ARTICLE IV. DUES

SECTION 1. Honorary members shall not be required to pay dues and shall receive the Journal and other publications without charge.

SECTION 2. The annual dues of an Active or Associate Member of the Society shall be five dollars ($5.00), which includes the cost of one subscription to the Society's Journal.

SECTION 3. The annual dues of a Student Member of the Society shall be three dollars ($3.00), which includes the cost of one subscription to the Society's Journal.

SECTION 4. Annual dues shall be payable in advance on January 1 of the calendar year. A bill shall be mailed to each Active, Associate or Student Member before that date, stating the amount of annual dues and the penalty for default. The Society's Journal shall be withheld from members pending payment of dues, and Active Members failing to pay by ten days prior to the Annual Meeting shall have their votes in the annual mail ballot disqualified. Members in arrears shall lose all privileges of membership until such arrears are met.

Article V. Resignation of Members

Section 1. Any member of the Society may resign at any time. Such resignation shall be submitted in writing to the Council.

Section 2. Any member who resigns under the provisions of Section 1 of this Article ceases to have any rights in the Society and ceases to incur further indebtedness to the Society.

Section 3. Any person who has ceased to be a member under Section 1 of this Article may be reinstated by unanimous vote of the Executive Committee subject to the payment of any outstanding dues and obligations which were incurred prior to the date when he ceased to be a member of the Society.

Article VI. Expulsion of Members

Section 1. Any member more than two years in arrears shall be dropped from the Society by the Executive Committee.

Section 2. Any member who is dropped under the provisions of Section 1 of this Article ceases to have any rights in the Society and ceases to incur further indebtedness to the Society.

Section 3. Any person who has ceased to be a member under Section 1 of this Article may be reinstated by unanimous vote of the Executive Committee subject to the payment of any outstanding dues and obligations which were incurred prior to the date when he ceased to be a member of the Society.

Section 4. Any member who, after being granted a hearing by the Executive Committee, shall be found guilty of a violation of the established principles of professional ethics, or shall be found guilty of having made a false or misleading statement in his application for membership in the Society, shall be asked to resign from the Society by unanimous vote of the Executive Committee. The decision of the Executive Committee in all matters pertaining to the interpretation and execution of the provisions of this section shall be final.

Article VII. Election of Officers

Section 1. The Standing Committee on Nominations shall consist of the President, the Past President, and the Prior Past President.

Section 2. The Standing Committee on Nominations shall nominate two or more candidates for each office to be filled. They must secure the consent of all candidates nominated.

Section 3. The Standing Committee on Nominations must submit their ticket to the President in time for publication in the October issue of the Society's Journal.

Section 4. For six weeks after the mailing date of the October issue of the Society's Journal, nominations in writing, signed by at least twenty Honorary Members or Active Members in good standing and accompanied by the written consent of the candidate, may be submitted to the President.

Section 5. At the expiration of the aforesaid six weeks period, the Business Manager will prepare and mail to each member, eligible to vote, a ballot listing all candidates properly nominated for each office. The candidates shall be listed alphabetically. With each ballot, the Business Manager shall send an official envelope having the member's name typed on the back.

Section 6. Each member voting shall cast one vote for each officer and shall return his ballot to the Business Manager in the official envelope carrying on the outside the written signature of the member submitting the ballot. Only ballots so prepared by members in good standing, and received by the Business Manager at his officially recognized address not later than ten days prior to the Annual Meeting shall be valid. The Business Manager shall indicate which ballots are valid and shall deliver the ballots unopened to the Standing Committee on Nominations for counting. The Standing Committee on Nominations shall personally supervise the counting of the ballots prior to the Annual Business Meeting. The candidates receiving the greatest number of valid votes cast for an office shall be declared elected to that office. In case of a tie, the Standing Committee on Nominations shall decide by a secret vote which of the candidates shall be elected.

Article VIII. Local Sections

Section 1. Upon petition of twenty members in good standing residing within an appropriate distance of a central point, the Council may authorize the formation of a Local Section and assign a specific territory to the Local Section. The Council may decline to authorize the formation of a Local Section when in its judgment such an organization would not be compatible with the interests of the Society.

Section 2. In the organizing meeting of the Section, all members of the Society residing in the territory assigned by the Council to the Section shall be eligible to vote.

Section 3. The Section shall be known as "The (name of place) Section of the Society of Exploration Geophysicists."

Section 4. The principal work of a Section shall be the holding of regular meetings for the presentation and discussion of papers of interest to its members.

Section 5. The Section shall adopt Bylaws which must be approved by the Council of the Society and shall be consistent with the Constitution and Bylaws of the Society.

Section 6. The election of District Representatives by the Local Sections shall be by secret ballot. The term of office of a District Representative shall be two years; however, if the Section is entitled to more than one Representative, one of the Representatives elected at the establishment of the Section or added as the result of subsequent growth of the Section, shall be elected for a one year term if this is necessary to prevent the terms of all District Representatives from expiring simultaneously.

Section 7. District Representatives shall be elected at least three weeks prior to the Annual Meeting of the Society and shall take office at the close of the Annual Meeting.

Section 8. The Secretary of the Local Section shall submit to the Secretary-Treasurer of the Society a report of each meeting of the Local Section or its governing board within two weeks after the meeting. He shall submit to the Secretary-Treasurer of the Society the names of all officers and committee members within two weeks after their election or appointment.

Section 9. Any Local Section which for two consecutive years has among its membership fewer than twenty members in good standing of the Society shall automatically be dissolved by the Council at its annual joint meeting. The Council may at any time dissolve any Local Section for reasons it deems good and sufficient.

Article IX. Finances of Local Sections

Section 1. The Society will pay the necessary operating expenses of a Local Section up to the sum of the following amounts: (a) $100.00 per year; (b) $50.00 per meeting up to four meetings per year; (c) $0.50 per member of the Society.

Section 2. The Treasurer of the Local Section shall forward, from time to time, his application for such portions of the sum provided in Section 1 as may be needed to the Secretary-Treasurer of the Society, who will arrange for the issuance of a check for the requested amount to the Treasurer of the Local Section.

Section 3. Prior to the Annual Meeting, the Treasurer of each Local Section shall transmit to the Secretary-Treasurer of the Society, for approval by the Council, an itemized statement of the expenditure of the funds received from the Society during the preceding calendar year.

Section 4. Allocations to a Local Section for the year in which it is established shall be in proportion to the fraction of the calendar year remaining.

Section 5. The Local Section may levy dues or raise funds in any other manner, subject to the approval of the Council. Payment of local dues shall, however, not be a prerequisite to participation in any activity financed wholly or in part with funds received from the Society.

Article X. Standing Committees

Section 1. The Society shall have the following Standing Committees: (a) Standing Committee on Nominations; (b) Standing Committee on Membership; (c) Standing Committee on Honors and

Awards; (d) Standing Committee on Publications; (e) Standing Committee on Program and Arrangements; (f) Standing Committee on Education; and (g) Standing Committee on Student Membership.

SECTION 2. Each Standing Committee shall have a chairman, appointed by the President unless otherwise specified in these Bylaws. The Chairman shall submit a report to the President of the Society at such intervals as the Chairman may deem advisable but at least quarterly. He shall submit to the Council at its annual joint meeting a report covering the activities of the Committee since the previous annual meeting.

SECTION 3. The Standing Committee on Nominations shall consist of the President who shall be chairman, the Past President, and the Past Prior President. Its duties shall be to nominate candidates for officers, to supervise counting the ballots and to declare the election of the officers as prescribed in Article VII of these Bylaws.

SECTION 4. The Standing Committee on Membership shall consist of three active members appointed for a period of one year by the President immediately following the Annual Meeting. One of the members appointed shall have been a member the preceding year. The Committee shall prescribe the manner of soliciting applicants for membership.

SECTION 5. The Standing Committee on Honors and Awards shall consist of five active members, none of whom shall have been members of the Society less than five years. The senior member of the Committee shall retire after the Annual Meeting. Vacancies shall be filled by the President. The Committee shall recommend candidates for election to Honorary Membership to the Council. The Committee shall recommend to the Council the establishment of Honors and Awards and shall recommend candidates for all established Honors and Awards of the Society to the Council.

SECTION 6. The Standing Committee on Publications shall consist of five active members who shall serve a two year term concurrent with the Editor and who shall be appointed by the Editor. The Committee shall have the duty of advising and assisting the Editor. The Editor shall appoint the Chairman of this Committee.

SECTION 7. The Standing Committee on Program and Arrangements shall consist of the Local Representatives plus three to ten additional active members appointed for a term of one year by the Vice-President, who shall be Chairman. The names of the members of the Committee shall be published in the July issue of the Society's Journal. The Committee shall have the duty of assisting the Vice-President in arranging and holding the Annual Meeting.

SECTION 8. The Standing Committee on Education shall consist of five active members appointed for one year by the President. The Committee shall promote effective geophysical education.

SECTION 9. The Standing Committee on Student Membership shall consist of five active members appointed for one year by the President. The Committee shall encourage the interest of students in geophysics and the Society.

SOCIETY OF EXPLORATION GEOPHYSICISTS

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Thomsen, Harry L.
Totten, Stanley W.
Wantland, Dart
Zimerman, Sam

Golden
Anderson, Thomas P.
Blakeman, Edmund R.
Bohanan, Wayne F.
Bowlby, Clarence W.
Bowling, Dewey D.
Brooks, Robert R.
Brown, Karl K. Jr.
Busteed, W. J.
Dickinson, Arthur S.
Diker, Salahi
Doss, Carson L.
Endacott, Foster E.
Fitzpatrick, Harvey J.
Gude, Arthur J. III
Hill, Brian B.
Holmer, Ralph C.
Jackson, Wayne H.
Jones, Ralph H.
Kerr, William W.
Leaf, Howard W.
Mantooth, Montie C.
May, Thomas O.
McFadden, Darrah H. Jr.
Meader, Robert W.
Miller, Richard
Murphy, William
Neill, Calvin F.
Newell, James W.
O'Boyle, Charles C.
Petrocco, John
Sanlav, F. M.
Scudday, Edwin R.
Sheehan, James B.
Siegfried, Richard C.
Smith, Dick
Stommel, H. E.
Tarbox, George E.
Throop, William H.
Vidal, Francisco F.
Voukovitch, Boris S.
Wallace, John J.
Wise, Richard A.
Wolikowski, A.
Woodward, Thomas C

Leadville
Searls, Robert J.

Longmont
Hayes, John R.

Pueblo
Berwick, J. D.
Ozman, D. D.

CONNECTICUT

Bethel
Legrand, J. C.

Ridgefield
Doll, H. G.

Wilton
Aiken, Charles B.

DELAWARE

Wilmington
Budd, M. R.
Johnson, N. G.
Lawrence, Robert W.

DISTRICT OF COLUMBIA

Black, R. J.
Bates, Charles C.
Bhattacharya, P. K.
Brenner, Morris
Brown, C. B.
Hawkes, H. E.
Hoffman, Malvin G.
Joesting, Henry R.
Kendall, J. M.
Martin, James M.
McGhee, George C.
Muzzey, David G. Jr.
Ritzmann, O. F.

FLORIDA

Brooksville
Howell, Theo. M.

Coral Gables
Blanchard, Wm. G.

Miami
Gilmore, Marion H.

Panama City
Jones, J. Byron

GEORGIA

Atlanta
Straley, H. W. III

Whitesburg
Hilley, James F.

IDAHO

Idaho Falls
Romer, Leo N.

ILLINOIS

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Lee, Lynn K.
Evanston
Amin, S. R.
Krumbein, Wm. C.
Siegert, A. J. F.
Manito
Van Orstrand, C. E.
Mattoon
Drake, Wm. R.
Mt. Carmel
Horton, H. M.
Mt. Vernon
Rutherford, H.
Olney
Davies, Nathan C.
Roodhouse
Dunaven, W. A.
Sidney
Everitt, James
Urbana
Nash, Cleve C. Jr.

INDIANA

Boonville
House, H. M.
Brazil
Irby, W. L.
Evansville
Combs, Edward J.
LaFayette
Serviss, Fred L.

IOWA

Ames
Roy, Chalmer J.
West Burlington
Wallis, Thomas F. Jr.

KANSAS

Kansas City
Jones, Harold H.
Lawrence
Dreyer, Robert M.
Liberal
Staples, Guy W.
Ness City
Hartley, T. R.
Wichita
Geiser, David T.
Mercier, V. J.

KENTUCKY

Berea
Huff, Allan L.
Lexington
Dobrick, Edward G. Jr.

LOUISIANA

Baton Rouge
Drews, Theodore E.
Geyer, Robert L.
McDougall, John E.
Penny, R. T.
Wang, Kia Kang
Crowley
Whatley, Sam T.
DeRidder
Whitsitt, C. D.
Donaldsonville
Faubion, Charles G.
Franklin
Adams, Leland C.
Hammond
Courtney, E. A.
Houma
Albers, W. F.
Augustat, George
Bramlette, John E.
Foster, A. D.
Lewis, Karl E.
Moore, Robert R.
Nash, R. L. Jr.
Proffitt, Jack M.
Rim, Herbert G.
Sadler, John Warren
Spencer, Samuel A.
Sturdevant, John M.
Teufel, Virgil W.
Waggoner, J. Woodrow
LaFayette
Conley, H. R.
Fischer, L. F.
Guseman, L. F.
Lee, J. E. Jr.
Morton, A. G.
Palmer, John C.
Shepherd, C. K.
Lake Charles
Cowie, Roger H.
Dexter, Lawrence N.
Dunwoody, Robert H.
Jasinski, E. J.
Reichert, H. C.
Van Cleave, R. F.
Leesville
Jewell, David F. Jr.
Monroe
Nichols, E. Turnley
Morgan City
Coffeen, James A.
Elliott, C. H.
Farrow, B. D.
Gautreaux, J. H.
Jeffcoat, L. E.
Jones, T. L.
New Orleans
Atwater, Gordon I.
Brown, L. I.
Burton, Gerald A.
Courtney, C. J.
Gregory, Carter H.
Harvey, A. G.
Holekamp, O. G.
Hoover, J. W.
Howe, Ralph H.
Howes, Thomas B.
Hughson, Barrett B.
Johnson, Byron K.
Kaiser, George B.
Levorsen, Robert I.
Mabry, Delord R.
Meitzen, J. B.
Northrop, Joseph W. III
Oudt, F. W.
Petersen, Harluf G.
Poirier, O. A.
Rodrigue, Louis G. Jr.
Robert, Kearny
Smith, Neal J.
Sprague, Robert L.
Stumpf, L. B.
Suggs, R. L.
Texter, John W.
Todd, James H.
Treybig, B. H. Jr.
Upshaw, Raleigh W.
Walker, J. E.
Ware, W. E.
Watson, Robert E.
Wegener, R. H.
White, Wm. H.
Wiley, W. B.
Zebal, George P.
Opelousas
Shafer, Russell E.
Wier, Joe R.
Shreveport
Baker, Glenn J.
Barret, Wm. M.
Baum, Robert
Blanchard, Charles H.
Bloomer, P. A. Jr.
Borys, Edmund
Brewer, R.
Bryan, Carl L.
Buchner, Harry M.
Burroughs, B. B.
Carter, R. W.
Caster, E. L.
Clark, Wm. W.
Clarke, Clem S.
Freeman, L. I.
Goebbel, L. A.
Howard, G. C.
Keen, C. D.
Knight, Fred G.
Mix, A. E.
Moore, C. F. Jr.
Owen, H. J.
Pearce, Roy W.
Rosencrans, R. R.
Taylor, John E.
Tilleux, H. O.
Wagoner, George E.
Walker, J. R.
Wilson, R. M.
Slidell
Schneider, John J. Jr.

Sulphur
Elms, R. G.
Moore, James A.
Vidalia
Campbell, Richard A.
Ville Platte
Reynolds, Robert D.

MARYLAND

Baltimore
Swartz, J. H.
Berwyn
Bleil, David F.
Bethesda
Maxwell, E.
Mt. Rainier
Doolittle, Russell C.
Silver Spring
Erickson, Anton
Melton, Ben S.
Opland, Homer N.
Willis, Floyd Jr.

MASSACHUSETTS

Belmont
Woodward, Richard H.
Cambridge
Bean, Robert J.
Crary, A. P.
Faul, Henry
Haskell, Norman A.
Madden, Theo. R.
Harvard
Leet, L. Don
South Lincoln
Tripp, R. Maurice
Waltham
Bradford, Donald C.
Peoples, J. A. Jr.
Weston
Linehan, Daniel, S.J.
Woods Hole
Hersey, J. B.
Worcester
Horner, Robert S.
Worthington
Paul, K. W.

MICHIGAN

Ann Arbor
Wilson, James T.
Detroit
Wesley, Richard H.
Houghton
Bacon, Lloyal O.
Longacre, Wm, A.
Ishpeming
Boyum, Burton H.
Sumner, John S.

MINNESOTA

Minneapolis
Armstrong, Lee C.
Mooney, Harold
St. Paul.
Martin, Donald R.
Wetzel, W. W.

MISSISSIPPI

Brookhaven
Webster, Felix H.
Canton
Cooper, Stuart H.
Evans, Hugh Jr.
Roberts, Francis A.
Jackson
Chang, T. Y.
Gaby, Ewin D.
Hathaway, M. S.
Myers, M. D.
Phillips, Robert R.
Pretzer, Dwayne L.
Laurel
Gallaway, R. L.
McComb
Herr, H. K.
Walling, F. Rex Jr.
Natchez
Ferguson, J. G.
Gulmon, Gordon W.
Jong, Aart de
Strange, Booth B.
Vicksburg
Perret, Wm. R.
Woodville
Nutt, Charles H.
Valder, Clayton S. Jr.

MISSOURI

Fredericktown
Phebus, James E.
Joplin
Marsh, Wm. T.
Kansas City
Barton, Jackson M.
Rolla
Gabriel, V. G.
St. Louis
Abbott, Wm. C.
Black, Rudolph A.
Blum, Vincent J., S.J.
Bohrer, Samuel
Brewer, Max C.
Engelhardt, James R.
Honnell, Pierre M.
Lurton, Nelson E. Jr.
MacElwane, J. B., S.J.
Miller, Cecil C.
Moore, Fred E.
Nuttli, Otto W.
Patterson, Wm. A.
Robertson, Florence
Scharon, Harry L.
Stearn, Noel H.
Wilkat, Albert O.
University City
Kisslinger, Carl

MONTANA

Glendive
Calledare, Wm. C. Jr.
Miles City
Colvin, C. E.
Roundup
Bartel, Robert R.

NEBRASKA

Eustis
Wall, Carl C.
Falls City
Riess, Malcolm
Fremont
Holm, E. Richard
Omaha
Latenser, James S.
Rushville
Gibbs, Kenneth E.

NEW JERSEY

Fort Monmouth
Bowsky, Merle C.
Irvington
Dinstel, Woodrow L.
Montclair
Gilbert, Erle W.
Pitman
Nicholls, Charles W.
Princeton
Pekeris, C. L.
West Point
Schwab, Robert

NEW MEXICO

Albuquerque
Duffner, Ralph T.
Lohse, J. M.
Moore, Arthur A. Jr.
Paddison, L. J.
Wells, R. G.
Whelan, Mark
Artesia
Rees, W. W.
Aztec
Coan, G. B.
Jackson, Henry A.
Carlsbad
Corbin, L. P.
Haynes, Clifford G.
Pratt, Wallace E.
Williams, Frank E. Jr.
Dulce
Sprinkle, Don L.
Hobbs
Hillis, Donuil
Moore, J. Hiram
Thompson, Grady
Lovington
Shor, George G. Jr.
Portales
Brinnon, W. B.

Ferber, Herbert J.
Martner, Samuel T.
Roswell
Banta, H, E.
Ruidoso
Evjen, H. M.
Socorro
Clevenger, M. A.
Holmes, Charles R.

NEW YORK

Amawalk
Kelly, Sherwin F.
Brooklyn
Stimler, Saul
Great Neck
Vacquier, Victor
Mamaroneck
Herman, Alvin J.
New York City
Brant, A. A.
Brilliant, Renee M.
Bryan, A, B.
Dresbach, Chas. H.
Ewing, Maurice
Hardy, Willis W.
Hazen, George H.
Heezen, Bruce C.
Kaufmann, G. F.
Kogbetliantz, Ervand G
Kozary, Myron T.
Lynch, Joseph, S.J.
Ohman, John
Olson, W. S.
Racek, Edward W.
Skeels, D. C.
Thompson, R. R.
Vajk, Raoul
Whiton, H. F.
Winkler, Bruno O.
Worzel, John L.
Rochester
Petschek, Albert G.
Troy
Beers, Roland F.
Wellsville
Donnerstag, Philip
Young, Wilbur H. Jr.

NORTH CAROLINA

Chapel Hill
Goedicke, T. R.
Clayton
Powell, Wm. H. Jr.
Monroe
Houston, Robert S.
Raleigh
Miller, E. L. Jr.

NORTH DAKOTA

Bismarck
Bearden, Carl D.
Renden, Hugo R.
Minot
Gilmore, Robert J.
Hazelrigg, J. B.
Mataya, Jack L.

OHIO

Cleveland
Birkenhauer, Henry F., S.J.
Walter, E. J.
Dayton
Koenig, Palmer E.
Toledo
Hotchkiss, Hugh C.

OKLAHOMA

Ada
Hall, Owen B.
Antlers
Olson, Odell C.
Ardmore
Bartow, Ralph D.
Bartlesville
Allen, Wm. E.
Bondurant, J. E.
Bradley, R. M.
Brownlow, C. L.
Courtier, Wm. H.
Crenshaw, C. C.
Dissler, Ernest W.
Elliott, S. D.
Ericson, Harry B.
Hintze, A. J.
Johnson, E. W.
Johnson, J. R.
Kidd, R. L.
McMillan, Fred L. Jr.
Mendenhall, H. L.
Miller, Vincent
Nisle, Robert G.
Piety, R. G.
Rice, Robert B.
Tilley, Aubra E.
Tucker, R. H.
Bethany
Drake, Wm. R.
Blackwell
LaGreca, Sam
Chickasha
McNally, P. M.
Durant
Johnson, W. S.
Edmond
Jones, Leland W.
Elk City
Davis, David K.
Hill, Emmett T. Jr.
Young, T. Eugene
Enid
Braithwaite, Al
Caldwell, Walter T.
Clifton, R. L.
England, C. M.
Fort Sill
Jackson, Robert W.
Madill
Holland, R. D.
Langstroth, Ward T.
Muskogee
Capps, Alden L.
Voegeli, Richard A.
Norman
Fazekas, John E.
Schriever, William
Thompson, Wilbur L. Jr.
Oklahoma City
Abbott, Wayne R.
Ballard, James A.
Beebe, B. W.
Care, John L.
Cody, C. C.
Dunn, George V.
Fee, S. T.
Glover, Robert H.
Green, Thomas H.
Hadler, Harry G.
Holt, Thomas C.
Jackson, Jim C.
Johnson, Joseph C.
Kamitchis, James E.
Kurk, Edwin H.
Lambert, G. D.
Mahannah, R. S.
Perry, W. B.
Ratliff, D. W.
Roane, W. H.
Seifert, Wesley H.
Sellers, Charles C. Jr.
Smith, C. B.
Smith, Francis E.
Stones, J. Eugene
Swearingen, A. C.
Sype, Wm. R.
Tesar, Robert M.
Trombla, Lynn B.
Vaughan, Leslie L.
Watson, James M.
Wilson, James E.
Wolff, D. J.
Wood, Carroll A.
Pauls Valley
Holt, Thomas C.
Ponca City
Crawford, John M.
Culbertson, J. A.
Davis, Warren L.
Fickinger, D. E.
Hughes, Roland F.
Jordan, C. K.
King, Laurence K.
Prescott, H. R.
Searcy, Frank
Swan, Bird G.
Vorheis, Byron
Whitehead, L. E.
Prague
Klabzuba, Robert E.

Sayre
Rase, H. L. Jr.
Shawnee
Lukens, John P.
Moose, Dale H.
Schaeffer, Hugh C.
Smith, D. F.
Stillwater
Goetz, Louis P.
Tulsa
Abel, Karl W.
Andrews, H. H.
Arnold, T. G.
Balbin, Paul D.
Ballou, Albert L. Jr.
Barthelmes, Albert J.
Bazhaw, W. O.
Beightol, R. O.
Benson, A. E.
Bevan, Thomas J.
Bills, Robert N.
Bishop, F. L.
Blakey, Carl W.
Borman, Frank W.
Born, Wm. T.
Boucher, F. G.
Bowie, Duncan M.
Bowman, D. C.
Breck, Howard R.
Brown, Frank E.
Brown, Henry W.
Buffum, C. Emery
Cady, Francis H.
Campbell, Francis F.
Cash, Harvey Jr.
Christie, Norman J.
Christy, Robert F.
Clayton, Neal
Cochrane, David W.
Coffin, R. Clare
Connell, Joe E.
Cooley, E. H.
Cooper, Jack R.
Coryn, F. R.
Cowell, Frank M. Jr.
Cronin, Stewart
Crudup, Jack M.
Crump, W. W.
Crumrine, Kenneth C.
Cunningham, Wm. J.
Damon, Everett F.
Davenport, Robert
David, D. R.
Dawson, L. Decker Jr.
Day, Chas. E.
Deegan, Charles J.
Dimmick, Opie
Doll, W. R.
Duller, Charles E.
Dunagan, Lillard C.
Dyk, Karl
Dzwons, George S.
Echo-Hawk, Owen
Edmonson, Carl L.
Egan, Daniel G.
Eisler, Joseph D.
Engle, A. Wendell
Erdahl, Wm. M.
Etnyre, John B.
Evans, David L.
Evans, Julian F.
Faust, L. Y.
Fearon, R. E.
Fentem, R. L.
Ferguson, John L.
Ferris, Craig
Finn, Robert S.
Flemming, Howard
Foster, G. A.
Franklin, John V.
Friendly, Jack L.
Frossard, Robert L.
Fruehling, S. W.
Garner, J. P.
Garpner, Erik U.
Gemmer, R. W.
Gilkison, Don
Gilliam, J. T.
Gilmore, John A.
Gilmour, Andrew
Giulio, Stanley E.
Golosovker, S.
Green, Robert P.
Guntharp, John H.
Hachenberg, Charles D.
Hadley, Charles F.
Handley, E. J.
Harbach, Robert G.
Harlow, Robert O.
Harlton, Bruce H.
Harper, James C.
Harris, D. B.
Hartline, Ralph E.
Harvey, Castle J. C.
Hawes, Julian J.
Hawkins, J. E.
Hays, Clyde L.
Heap, W. O.
Henderson, Bill
Hidy, John H.
Hobart, Henry M. Jr.
Hollis, Jack L.
Hopkins, James S.
House, A. Maxwell
Hovi, Theodore W.
Hurry, Clare N.
Ingle, Gerald W.
Innes, Arland I.
Jackson, Judson G.
Jackson, Kenneth
Jameson, Chet H. Jr.
Jeffers, Paul H.
Jones, John P.
Jones, V. L.
Keeling, J. A.
Kendall, R. C.
Keselik, Joseph
Keys, Robert T. Jr.
Kezeler, J. L.
Kiess, Myron C.
Kimball, Jack E.
Kittredge, F. R.
Knowles, J. G.
Koeppel, B. W.
Lambkin, Woodrow W.
Lang, Harold M.
Larguier, Leonard J.
Lash, Charles C.
Lawrence, K. M.
Laws, J. O.
Lea, M. H.
Leas, Ruth R.
Lockard, L. F.
Locke, Edgar R.
Ludwick, C. C.
Lynn, Ralph D.
Lyons, Paul L.
Manhart, T. A.
Maras, Robert G. Jr.
Martin, Dick
Mathieson, Raymond L.
Maxey, J. R.
Mayes, Tom D.
McAlister, C. H.
McClure, C. E.
McCollum, E. V.
McCracken, Guy I.
McManis, L. B.
McNatt, E. M.
Mehringer, A. P.
Miller, James W.
Miller, Nash H.
Milton, A. A.
Mitchell, Fielding L.
Mooney, Donald N.
Moore, Homer C.
Moore, Leland E.
Moore, W. Lee
Mossman, R. W.
Nash, John M.
New, James R.
Newton, George R.
Novelly, Walter O.
Oliphant, Charles W.
Owen, H. E.
Owen, John E.
Palmer, John E.
Parker, G. A.
Patterson, A. R.
Pennington, Wallace E.
Peterson, Glen
Petsoff, George J.
Pirson, Sylvain
Preston, B. G.
Pugh, W. E.
Raborn, Smiley Jr.
Rankin, C. T.
Reed, David E.
Reed, George W.
Reid, A. C.
Richardson, J. W.
Rickel, Wesley K.

Ricker, Norman
Riggs, R. J.
Roark, James J.
Roberts, P. E.
Robinson, Wm. J.
Roemer, C. D.
Rollins, J. C.
Romberg, Marvin
Ross, C. M.
Ross, R. B.
Rupnik, John J.
Rutledge, Richard B.
Schad, Charles A.
Scott, C. B.
Seaman, L. O.
Sharpe, Joseph A.
Sibley, W, B.
Silverman, Daniel
Smith, Frank B.
Southgate, Tom F.
Sparks, N. R.
S. Ross, John T.
Stephens, T. V.
Stotler, Thomas C.
Stover, Edward B. Jr.
Strachan, Clyde G.
Strange, John P.
Swift, Gilbert
Taylor, Albert
Taylor, Garvin L.
Teegarden, Tom
Tellington, Wentworth J.
Thayer, J. M.
Thomas, Thomas J.
Thralls, H. M.
Van Orden, Keene C.
Vernon, Jess
Vlasak, Frank E.
Von Croy, Stefan
Warner, D. F.
Warren, Howard B.
Watson, Allan P.
Watson, Robert J.
Weatherby, B. B.
Weichert, David R.
Weichert, R. F.
Wells, Wm. M.
Westby, G. H.
Widess, M. B.
Williams, P. S.
Williams, Richard
Wilson, James N.
Winn, Clayton N.
Winnek, J. R.
Zongker, Ray C.

Watonga
Strayhorn, Tom R.
Strozier, Robert J.

Waurika
Johnson, Lloyd

Weleetka
Gregory, J. W. Jr.

Woodward
Barnes, R. H.

OREGON

Aurora
Lester, O. C. Jr.

John Day
Clup, Harold A.

PENNSYLVANIA

Bethlehem
Agocs, W. B.
Gallagher, Robert T.
Pentz, Harold H.

Bradford
Barber, R. C.

Ebensburg
Bender, Fred A.

Erie
Wuenschel, Paul C.

Gibsonia
Fink, Paul O.

Norwood
Bazzoni, Charles B.

Oakmont
Smith, Douglas H.

Palmerton
McMurray, Howard V.

Philadelphia
Jensen, Homer
Peterson, Eugene F. Jr.

Pittsburgh
Affleck, James
Allen, Frank T.
Allon, Michael
Backman, John E.
Bailey, Lothrop H.
Barnum, Warren R.
Barton, Edward I.
Butler, Mark D.
Cerveny, Philip F.
Cook, D. E.
Davis, David A.
Diveley, Paul R.
Eckhardt, E. A.
Elkins, Thomas A.
Gardner, Louis W.
Gealy, Wendell B.
Gunn, J. E.
Hammer, Sigmund I.
Hastings, W. K.
Hazen, Wm. G.
Herron, Robert C.
Jones, R. W.
Kilborn, J. M.
Lamb, Wm. C.
Meszaros, W. A.
O'Donnell, T. J.
Palmer, E. M.
Peters, L. J.
Pomeroy, R. F.
Reiser, Robert C.
Robinson, John L. Jr.
Robinson, W. Bernard
Watson, George R.
Wert, Carl M.
Wickerham, M. D.
Wigbels, Frank B.
Wyckoff, R. D.

Ridley Park
Johnson, F. L.

State College
Capatch, Victor F.
Hill, Rcbert G.
Howell, B. F. Jr.
Jones, Donald W.
Keenan, Curtis H.
Keller, George V.
May, Harold G.
Stuart, David J.

Verona
Muffly, Gary

Williamsport
Grant, H. Lowry

SOUTH DAKOTA

Aberdeen
Newquist, John W.

Newell
Jennings, D. Mitchell

TENNESSEE

Oak Ridge
Garrett, George A.

TEXAS

Abilene
Van Siclen, DeWitt C.

Alvin
Beck, Ronald E.

Amarillo
Davidson, G. Bowen

Athens
Frost, Holloway H.

Austin
Baker, Charles M.
Horton, C. W.
Hughes, Darrell S.
Jones, Charles R.
Jones, Hal J.
Massingill, George S.
Proctor, John L.
Romberg, Frederick E.
Thomas, Earl
Tribbey, Roy J. Jr.

Ballinger
McMahan, J. R. Jr.
Whaley, Wm. J. Jr.

Beaumont
Conklin, Glenn M.
Davis, Wm. W.
Dodd, Lavon C.
Ellis, L. G.
Henson, Robert L.
Hagemann, Richard F.
Hollingsworth, W. E.
Jenneman, Vincent F.
Koenig, Robert J.
Konz, Leo W.

McCormack, Harold R.
Millington, John W.
Richert, B. E.
Viterbo, Verne D. Jr.
Williams, C. E.
Winterhalter, Alfred

Beeville
Jackson, R. S.

Bellaire
Cowles, Laurence G.
Garrison, Phil H.
Herzog, Gerhard
Hibbler, A. J.
Hubby, L. M.
Lee, B. D.
Manes, O. B.
Morris, H. B.
Pranglin, John A.
St. Germain, Raymond J.

Big Lake
Burton, Raiford H.

Big Spring
Barnes, Chester F.

Brady
Cross, James H.
Herlihy, Daniel E.
Opitz, E. E.
Watts, Evan

Brownwood
Salyer, James L.

Canadian
Pearce, Warren N.

Center
Ruhlen, W. W

Childress
Arnold, W. J.
Sears, F. Dean
Shannon, Charles A

Cisco
Hart, M. M.
Reeves, James R.
Shoupe, Hal W.

Coleman
Cheney, M. G.

College Station
McDowell, A. N.
Weekes, Donald F.

Columbus
Etheridge, K. E.

Corpus Christi
Barber, T. D.
Bolinger, John W.
Chappel, Clifford M.
Daughterty, C. G. Jr
Dunbar, R. O.
Macdonell, M. E.
McCaleb, Maurice M.
Randolph, J. R.
Reivere, Romaine
Sharpe, John M.
Starr, A. G.
Terrasson, Paul L.
Teasley, Samuel A.
Weatherby, S. P.
Zazvorka, Jerry Jr.

Dallas
Adams, H. R.
Agnich, Fred J.
Alcock, E. D.
Amis, W. H. Jr.
Andrews, Reagan H.
Appendino, John
Archer, Milton
Armstrong, Orvan H.
Arnett, R. D.
Arnold, Kingsland
Autrey, C. B.
Autrey, D. W.
Ayres, J. Otis
Baker, M. E.
Batson, James B.
Blattner, Sanford D.
Bonebrake, Walter C.
Boulware, Robert A.
Brannian, Ross E.
Brock, Fred A.
Broding, Robert A.
Brown, H. Hallock
Burg, K. E.
Butt, Harding
Byers, Richard E.
Campbell, E. L.
Capp, J. T.
Carlberg, Charles E.
Carpenter, Michael C.
Carrow, James O.
Carson, Roe W.
Cathey, John A.
Chamberlin, Chester W.
Clewell, Dayton H.
Clifford, O. C. Jr.
Cloepfil, Gordon D.
Cobb, Howard L.
Collingwood, D. M.
Congdon, R. L.
Conover, George E.
Cornell, Russell B.
Cortes, H. C.
Coursey, W. Dudley
Crump, Oscar M.
Dahm, C. G.
Deer, Joe H.
Deford, H. L.
DeGolyer, E. L.
DeJournette, R. D. Jr.
Dienesch, Jean
Dobrin, Milton B.
Dobyns, D. R.
Dodson, Herbert F.
Donnally, Chester J.
Douglas, Norvel
Dugan, Albert F.
Dundon, Robert F.
Dunlap, H. F.
Edmonston, W. J.
Eichelberger, A. M. Jr.
Elston, Chris H.
Everett, R. D.
Fain, Edgar A.
Finch, Elmer H.
Fisher, Guy W.
Fisk, F. K.
Floyd, Roy
Foote, Lewis C.
Garrett, M. M.
Geer, J. T.
Gill, John D.
Gillin, John A.
Godbey, John K.
Gaither, Jerrel
Godell, John J.
Granberry, H. E.
Green, Cecil H.
Green, W. G.
Guipre, Robert W.
Haggarty, Patrick E.
Harkey, W. J.
Harkness, T. O.
Harvey, Wm. P.
Hawk, Riddell L.
Hawthorne, W. W.
Hayes, Quinlivan
Heaps, Stanley
Heggy, Homer L
Henderson, J. B. H.
Henderson, Oran C.
Henderson, Ross
Hendricks, J. L.
Heroy, W. B.
Heroy, Wm. B. Jr.
Hieatt, Herbert F.
Hightower, C. H.
Hodge, P. V.
Hogg, W. B.
Holbert, Murrell
Holmes, O. M.
Hooton, John A.
Horn, J. W.
Howard, Ben R.
Huey, Wallace F.
Isensee, George W.
Jennings, Bruce M. Jr.
Johnson, Melvin C.
Jones, M. P.
Jonsson, J. E.
Jopling, D. W.
Jordan, James B.
Karcher, J. C.
Kelsey, Martin C.
Kennedy, Edward P.
Kennedy, Frank H. Jr.
Kern, Jack C. Jr.
Kiesler, Ernest A.
Kovelan, Edward C.
Kyle, Ramon
Lawrence, Philip L.
Lester, John A.
Leventhal, Stanley M.

Linwell, Martin V.
Lipscomb, Earl W.
Lipson, Leonard B.
Logue, L. L.
Lohrentz, Don
Lomax, C. J.
Loyd, Edward R. Jr.
MacNaughton, L. W.
Martin, John L.
McBurnett, Harry Jr.
McBurney, C. G.
McCain, Hugh Jr.
McCarver, Holland C.
McCready, H. J.
McDermott, Eugene
McGiboney, James C.
McKay, A. E.
McLoad, Kenneth W.
McManus, Jack V.
McMullin, Elbert F.
Menefee, James C.
Mickey, Wendell V.
Milstein, Mark
Minton, J. P.
Mitchell, W. R.
Molinar, J. J.
Moody, Herbert H.
Moon, Jake
Moore, F. A.
Moran, Ray O.
Morgan, Charles G.
Musgrave, Albert W.
Napier, T. S.
Nash, Paul E.
Newton, W. W.
Nogami, Henry H.
Nugent, Roderick M.
Oksa, Donald R.
Olson, R. W.
Owings, B. F. Jr.
Ownby, Byron
Park, Noel R.
Paslay, L. C.
Peacock, H. B.
Pellillo, M. J.
Penn, Edgar R.
Pernell, J. H.
Perryman, J. D.
Peters, Jack W.
Pittman, C. V. A.
Porter, C. P.
Quarles, Miller Jr.
Rainey, Richard H.
Ralph, Pierson M.
Ransom, J. H.
Ransone, W. R.
Reagor, Edward C.
Reeves, W. A.
Reingans, Gerald A.
Renner, Darwin S.
Rettger, Robert E.
Robinson, George W.
Robinson, Thomas E.
Rollins, J. Frank
Roper, W. B.
Rosaire, E. E.
Rose, H. W.
Rouse, John T.
Russell, Dallas L.
Rust, Carl F.
Sandusky, P. M.
Sanford, Robert E.
Seiler, Geo. E.
Shook, Earley M.
Shoup, George J.
Shugart, T. R.
Smiley, W. G. Jr.
Smith, A. Horton Jr.
Smith, Charles W.
Smith, Randolph
Smith, Victor W.
Smithwick, H. B.
Sole, Lewis H.
Sorrels, B. J.
Spivey, Sherman R.
Stanfield, J. W.
Steel, D. M.
Stehr, Raymond A.
Stephens, J. L.
Stulken, E. J.
Summers, Gerald C.
Swanson, Jack G.
Thompson, James E.
Thomsen, Carl J.
Toomey, E. J.
Tootenham, W. M.
Towles, Henry C. Jr.
Travis, Fred L.
Trostle, T. D.
Trunrud, Roy W.
Valkus, James W.
Waller, John A. Jr.
Walsh, T. N.
Walters, C. G.
Walton, Britain W.
Walton, Paul L.
Wardell, Richard H.
Warren, Paul R.
Warrick, Thomas R.
Waters, Kenneth H.
Wayland, J. R.
Weisbrich, R. A.
Westgate, Christine
White, Gale
Whiting, Gertrude
Whorton, L. P.
Williams, Charles C.
Williams, Floyd J.
Wissemann, Hilmer J.
Woodrich, Frank W.
Woods, J. P.
Woolley, William C.
Yost, W. Jacque
Zwiebel, George H. Jr.

Eastland

Giddens, O. F.

Ft. Worth

Anderson, Owen Wm.
Baird, Walter D.
Campbell, David B. Jr.
Dana, Anna M.
Dana, R. H.
Donley, John C.
Dudley, Raymond W.
Dunlap, A. D.
Gemmill, Edward J.
Harrington, G. Jr.
Harris, Sidon
Hollingsworth, W. Wise
Itten, Howard
Johnson, James F.
Kendall, John M.
Kerbow, R. B.
Kerr, V. Robert
Laneve, R. O.
Lang, R. H.
Ledyard, Paul H.
Long, C. J.
Lovejoy, J. B.
McLemore, Ethel W.
Mitchell, James R.
Morehead, Jack N.
Morris, James L.
Mortlock, F. O.
Normand, S. R.
Parks, Robert R.
Patterson, Harold F.
Riley, James K.
Rudolph, Wm. E. Jr.
Sanders, C. W.
Simpson, Lee
Suggs, M. L.
Van Steenbergh, S. K.
Warren, Kirby J.
Wilson, John H.
Wilson, John H. II
Yates, Cal

Garland

Baker, Buford M.
Stanton, Austin N.
White, R. H.
Winn, Billy

Glen Rose

Waddell, V. H.

Goliad

Hargis, A. V.

Grand Saline

Jones, Edward C.

Grapevine

Deacon, L. E.

Hamilton

Stiles, E.

Houston

Aderman, C. V.
Adler, Joseph L.
Akkerman, Richard P.
Allen, Stanley R.
Anderson, John F.
Andrews, W. W.

Arsenault, Charles A.
Arthur, M. A.
Athy, L. F.
Bader, Glenn E.
Barbisch, J. B.
Barnes, A. L.
Barry, Adelbert
Bartlett, David
Bartow, Arthur I.
Beeman, Keith R.
Beeth, Donald
Bell, Olin G.
Bemrose, John
Benke, M. L.
Bennett, Roy F.
Berg, G. A.
Berleth, Wm. H.
Bertram, A. C.
Bible, John L.
Black, J. P.
Blau, L. W.
Boudreaux, Edward A.
Briard, Vernon E.
Briggs, Robert B.
Brooks, James A.
Broussard, C. H.
Broussard, D. F.
Brown, Andrew
Brown, Hart
Buckner, Guy O.
Bugbee, J. M.
Bunsen, A. W.
Burke, Wm. H. Jr.
Burkhalter, H. L.
Burnett, A. C.
Butler, Robert E.
Butler, W. W.
Byers, John W.
Campbell, H. H.
Carlton, Dave P.
Carr, George W.
Carter, Ray K.
Catchings, Robert F.
Charrin, Paul J. D.
Charske, Charles J.
Chernosky, Allen A.
Child, V. E.
Clark, George B.
Clark, W. O.
Claunch, Elton B.
Cloud, R. T.
Cole, R. C.
Cook, Paul C.
Cornelison, Boyd
Cram, Ira H.
Crary, Donald
Crowder, H. V.
Crowell, J. H.
Dausman, R. H.
Davis, Donald M.
Deussen, Alexander
DeWoody, D. A.
Dunway, J. H.
Duty, Robert S. Jr.
Duty, W. B.
Eby, J. Bryan
Farren, Paul
Fay, Charles H.
Feagin, Frank J.
Fennessy, W. J.
Ferguson, J. B.
Fishback, J. W.
Flude, J. W.
Fohs, F. Julius
Franklin, Louis
Freel, J. F.
Frosch, A.
Frowe, Eugene
Fuller, John C. J.
Gallie, J. F.
Gardner, Derry H.
Garrett, Wm. M.
Geyer, Richard A.
Gibson, Wm. H.
Giezendanner, S. S.
Gilliland, J. R.
Goldstone, Frank
Goss, Henry V.
Gould, Martin J.
Grange, Donald C.
Graves, Robert D.
Griffin, I. M. Jr.
Griffin, W. Raymond
Guiler, Mona D.
Guyod, Hubert
Hafner, W.
Hale, R. B.
Hall, T. O.
Hamil, A. B.
Hamilton, W. Brooke
Hammial, L. L.
Hanahen, P. M.
Hans, Edward
Happel, Henry H.
Happell, Henry H. Jr.
Hardy, Hugh W.
Harkins, Curtis P.
Harkins, T. I.
Hatcher, Stanley A.
Haynes, C. J.
Haynes, R. B. Jr.
Heintz, Karl O.
Henderson, M. R.
Henquet, R.
Hermont, Alfred J.
Herrod, Richard A. Jr.
Hess, Edith May
Hibbler, M. E.
Hill, E. Bruce
Hilton, R. C.
Hinson, C. C.
Hoard, J. O.
Holland, Taylor H.
Horvitz, Leo
Howell, Lynn G.
Hubbard, Charles L.
Hubbert, M. King
Hull, J. W.
Hunzicker, A. A.
Hutchinson, C. C.
Ivy, John S.
Jackson, G. L.
Jett, J. E.
Johnson, Earle W.
Johnson, Frank B.
Johnson, W. D.
Jones, E. E.
Jubran, Joseph K.
Judson, Sidney A.
Kannestine, F. M.
Kaufman, Sidney
Kimes, Albert
Klaveness, A.
Konkel, Philip M.
Kouri, Barton H.
Krause, Fred W.
Krieg, E. A. Jr.
Kriegel, H. C.
Kubik, Kasmier D.
Ladner, A. L.
Lamb, George B.
Larue, James E.
Lawhorn, O. T.
Lay, Roy L.
Lea, W. T.
Lee, W. B.
Legge, John A. Jr.
Leonardon, E. G.
Lewis, W. B.
Long, G. J.
Lowe, C. R.
Lowery, R. A.
MacAllister, C. T.
Mace, G. M. Jr.
MacMahon, A. M.
Mann, Ralph W.
Marr, John D.
Martin, E. C.
Martin, Sidney A. Jr.
Martyn, Phil F.
McCann, K. G.
McCollum, Burton
McCreary, Dosh T.
McCullagh, John Jr.
McDonnold, H. W.
McGee, John E.
McReynolds, Gregg F.
Melton, D. P.
Miller, Robert D.
Millet, M. J.
Mitchell, George D. Jr.
Monkhouse, John R.
Montgomery, George P. Jr.
Montgomery, J. C.
Moore, D. B.
Moore, James M.
Moore, James R. III
Morgan, Wesley H.
Mounce, W. D.

Mower, L. K.
Murrell, James T.
Myers, Charles E.
Neese, U. E.
Nelson, Wm. P.
Nettleton, L. L.
Neuman, L. J.
Newby, C. J.
Nichols, J. B.
Noonan, W. G. Jr.
Norris, C. G.
Nutt, W. T.
Osterhaudt, W. J.
Ostreim, R. N.
Palmer, R. L.
Parker, Kenneth L.
Parker, L. A.
Parker, Richard H.
Paschall, John P.
Patrick, H. G.
Pawley, Julian K.
Pena, Sam M.
Pollard, Jack C.
Postma, G. W.
Powell, Paul B.
Raines, Eli
Randle, Sam Jr.
Rasco, Wm. A.
Ray, Robert H.
Reed, Charles F.
Reynolds, F. F.
Rivers, Henry F.
Roberts, R. D.
Robinson, Edwin H.
Roever, Wm. L.
Rogers, Austin S.
Rogers, L. Brann
Rogers, Revill M.
Rogers, Sam D.
Rolshausen, F. W.
Roos, Lewis V.
Rosaire, L. G. Sr.
Rowe, Ural A.
Rusch, Peter J.
Ruska, Walter E. A.
Rust, W. M. Jr.
Rutherford, Robbie
Sappington, Chester
Sargent, R. L.
Sauls, James L.
Saville, W. G.
Schafer, Sidney
Schmidt, Henry
Schmuck, R. H.
Schofield, G. A.
Scholl, Louis A. Jr.
Schumacher, J. P.
Sears, Harold A.
Selig, A. L.
Sheets, Martin M.
Sherar, E. S.
Sherar, Stuart
Shettle, George O.
Shimek, E. J.
Sims, Sam E.
Shore, Harold F.
Slotnick, M. M.
Smith, A. E.
Smith, A. L.
Smith, Fred A.
Smith, H. C.
Smith, J. Angelo
Smith, Noyes D.
Smith, Warren H.
Somers, George B.
Spalding, C. T.
Speckels, Arthur W.
Spencer, J. S.
Steele, Dorothy A.
Steele, W. E. Jr.
Steenland, N. C.
Stewart, S. B.
Stone, George B.
Stouse, Maurice J. Jr.
Stratton, Everett F.
Swartz, Charles A.
Sweet, R. C.
Talley, H. C.
Taylor, Josiah
Taylor, W. Harlan
Terry, Russell D.
Thackston, W. C. Jr.
Thomas, Dick L.
Thompson, K. C.
Thompson, R. P.
Thomsen, Erik
Tucker, Robert L.
Urban, L. M.
Van Auken, John A.
Van Melle, F. A.
Vreugde, L. M. H.
Vreugde, T. L. J.
Wallace, C. R.
Wallace, Frank R.
Walling, Ray W.
Watt, J. S.
Weatherburn, K. R.
Weaver, Paul
Weingartner, R. A.
Wilber, Roscoe C.
Williamson, Lonnie C., Jr.
Wilson, E. E.
Wilson, Wm. H.
Wingett, R. O.
Winter, A. B.
Winter, George W.
Wolf, Alexander
Worden, Sam P.
Yeates, F. L.
Zagst, Edward F.
Zavoico, Basil B.
Zenor, Hughes M.
Zimmerman, C. C.
Zirbel, N. N.

Huntsville
Hurt, W. B.
Russek, I. W.

Iraan
Brack, John R.

Irving
Horn, Russell E.

Jacksonville
Mims, Robert L.

Kermit
Price, Justus V.

Kingsville
Edmonson, J. W. E.

Kirbyville
Wallner, Jackie D.

Lamesa
Wilcoxon, Robert B.

Littlefield
Willner, C. A.

Lockhart
Notley, W. E.

Lubbock
Conant, E. E.
Epperson, R. S.
Harman, Duane G.
Kendrick, Harold L.
Klaus, Hellmut
Morrison, M. S.
Smith, C. C.

Marshall
Brown, E. E.

McAllen
Harris, B. A.
Jett, Glendon D.

Mercedes
Hammons, F. H.

Midland
Arick, M. B.
Blake, E. F.
Bradley, H. W.
Breedlove, Ruth
Cornish, Lou G.
Feather, V. G.
Fischer, Leon
Forward, Fred
Gibson, George R.
Gibson, M. O.
Grimm, G. A.
Homan, W. L.
Hubner, B. G. Jr.
Jackson, O. B.
Jasper, Walter E.
Lemaster, Randall R.
Martin. G. W.
McKinsey, M. H.
Miller, Jeff E. Jr.
Mount, E. L.
Page, C. Newton
Park, Lee B.
Payne, C. Win
Pluta, Joseph S.
Porter, James C.
Rabensburg, N. J. Jr.
St. Clair, D. W.
Shock, Lorenz I.

Swords, Henry L.
Troseth, Frank P.
Uhrig, Leonard F.
Unger, Earle E.
Warren, R. P.
Winter, Niles B.

Miller Grove
Gore, Robert F.

Mount Pleasant
Wilson, James M.

Odessa
Davis, L. A.
Myers, John R.

Ozona
Percy, C. G.
Scott, D. L.
Voelker, H. L.

Palacios
Sisson, H. H.

Perryton
Kunkel, T. L.

Port Arthur
Pentecost, Claude D.

Port LaVaca
Brayton, A. E.

Post
Mason, Marshall Jr.

Rankin
Schneider, Louis E.

Raymondville
Bernard, Curtis R.

Riverside
Weinzierl, J. F.

Rocksprings
Harris, John

Rosenburg
Foote, W. L.

San Angelo
Green, Howard W.
Hunt, Eugene W.
Lawrence, Wm. P.

San Antonio
Allen, Thomas L.
Bennett, Elwin
Bissett, Clark
Crawford, Paul D.
Crawford, W. L.
Dawson, Herbert M.
DeLoach, E. L.
Donnelly, V. T.
Gragnon, Joseph N.
Hemmi, C. W.
Hunzicker, Vernon J.
Imle, John F.
Kelley, W. W.
Kirby, Gordon
Kohler, A.
Langford, Eldon W.
McDaniel, C. M. Jr.
Moore, Marion J.
Narvarte, P. E.
Parr, J. O. Jr.
Petty, Dabney E.
Petty, O. S.
Petty, Van A. Jr.
Pratt, R. B.
Ratliff, Guy M.
Roberts, Homer E.
Rudolph, P. J.
Rumsey, Paul T.
Schmidt, K. H. Jr.
Smitherman, Lynn A.
Smyrl, H. B.
Snow, Leland
Souther, J. B.
Tucker, Bill C.
West, Thomas S.
White, H. Paul
Wright, J. Dexter

Seguin
Blumberg, Roland K.

Seminole
Gaither, Harold L.
Hughes, John P.

Sherman
Schiflett, H. L.

Sinton
Larue, W. W.
Tidwell, Ellis M. Jr.

Slaton
Heard, James R.
Keese, James D.

Smithville
Grizzell, E. I.

Snyder
Davis, Rollin E.
Page, John S.
Reed, Paul C.

Spur
Poynter, Robert N.

Stamford
Willis, Howard A.

Sunray
Hardison, Stanley G.

Sweetwater
Gibson, G. D.
Horton, John D.
Peacock, R. H.

Tyler
Brooks, O. D.
Durham, Charles A.
Flowers, Jack F.
Tefft, Gerald H.

Waxahachie
Shackelford, Lewis L. Jr.

Wichita Falls
Bradley, Joe R.
Crain, Robert A.
Crider, Lewis C.
Mayfield, Wm. I.
McReynolds, Oliver B., Jr.
Neff, W. D.
Noble, Francis H.
Osmond, John C.
Samford, Mack
Strong, J. Randolph Jr.
Weeth, Charles A.

Woodville
O'Brien, Decatur

Yoakum
Clark, W. C.
McGuckin, Glenn M.
Woker, Leonard A.

UTAH

American Fork
Sargis, S. G.

Bountiful
Mabey, Don R.

Fort Douglas
Roller, John C.

Kamas
Zieve, Robert L.

Salt Lake City
Cook, Kenneth L.
Doan, Raymond E.
Done, Clark B.
Donohoo, H. V. W.
Hayes, Junius J.
Knittle, Richard B.
Krivoy, Harold L.
Larsen, Kenneth W.
Marquardt, Carlton M.
Smith, Darrell E.

Vernal
Patton, C. E.

VIRGINIA

Alexandria
Lipson, Edward
Nahas, Jack N.

Arlington
Perkins, B. Jr.

WASHINGTON

Quincy
Neibauer, Herman

Seattle
Paterson, Walter D.

Shelton
Rector, Richard S.

WISCONSIN

Madison
Woolard, George P.

WYOMING

Alcova
McCleary, Henry G.

Buffalo
Boring, Burl J.
Parker, Jesse G.

Casper
Boggs, William E.
Carter, Norman A.
Desmond, J. M.
Durant, C. P.

Ervin, Lynn D.
Fenwick, Willis H.
Gilmore, Robert A. Jr.
Greenlee, Paul
Hawpe, Franz M.
Heim, Jean W.
Hershelman, Wm. L.
Hoffman, John C.
Junger, Arne
Larson, Carl L. Jr.
Martin, Jack
McCoy, J. H.
McGrady, H. D.
Meade, George N.
Parker, John M.
Partridge, John F. Jr.
Schlundt, Herbert
Schombel, L. F.
Spencer, Jesse E.
Spencer, Leslie C.
Strange, O. A.
Van Der Weg, Klaas
Walczak, Michael J.
Whitt, Rayburn H.
Wilkinson, A. L.
Winfrey, D. B.

Gillette
Fillippone, Walter R.

Lander
Imle, Harry R.
Lankton, John M.
Williams, E. D.

Lusk
Stafford, C. J.

Newcastle
Martens, W. B.

Rawlins
Johnston, Frank M.

Riverton
Bixby, Robert H.
Long, Archie T. Jr.
Murray, Irvin B. Jr.
Rupert, James W. Jr.

Worland
Eastes, William T.

FOREIGN

AFRICA

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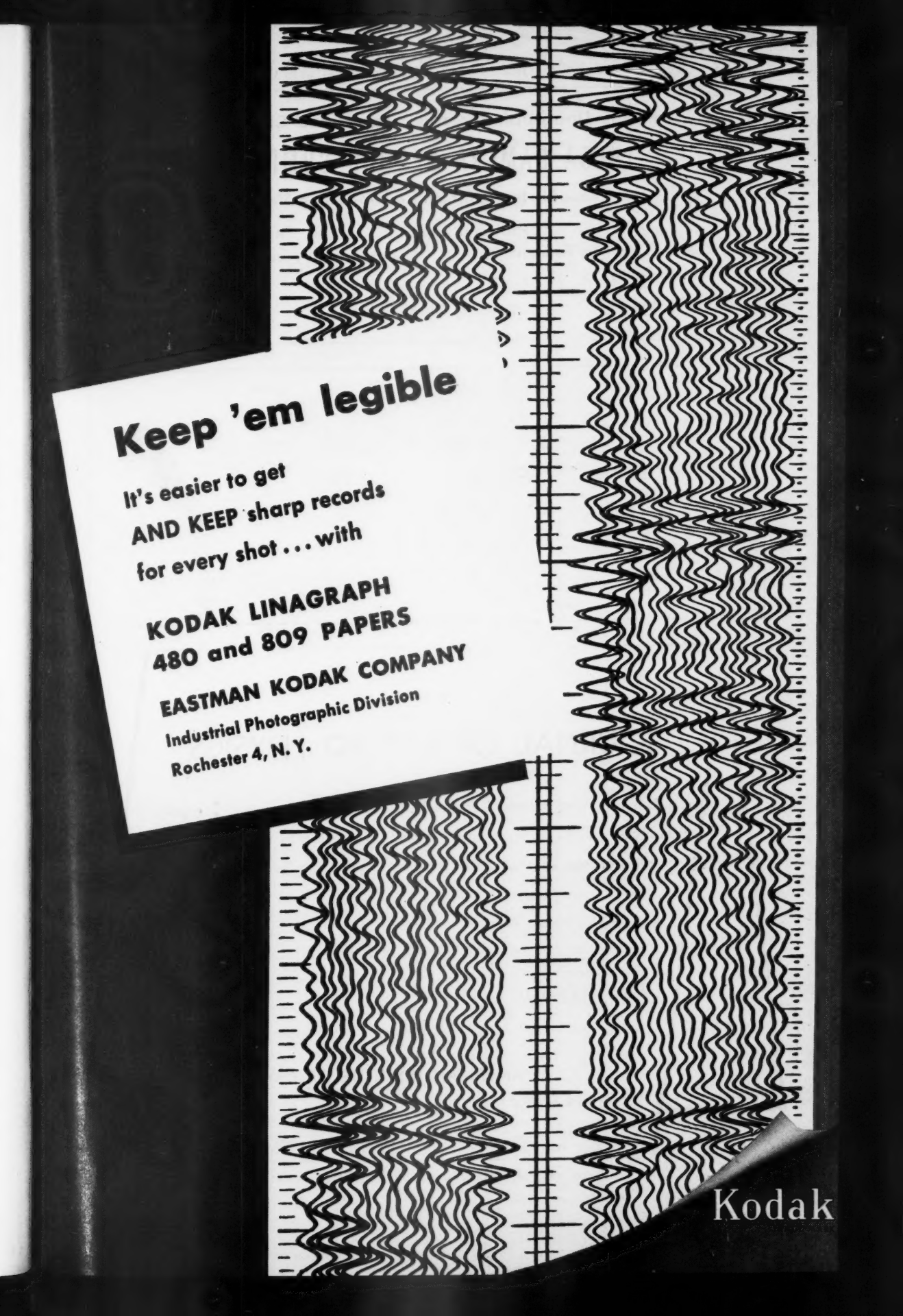
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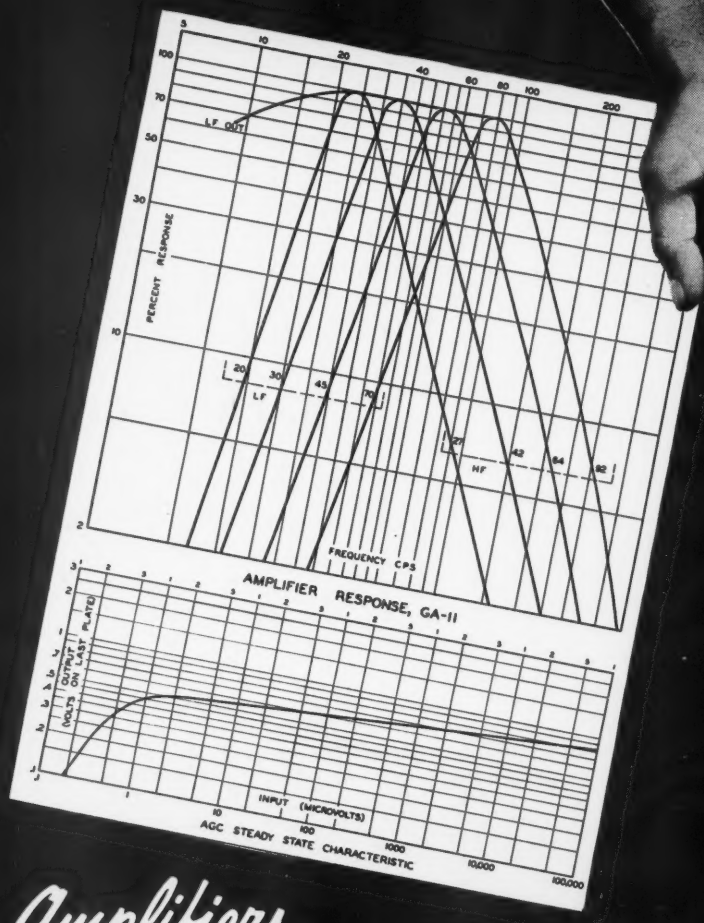

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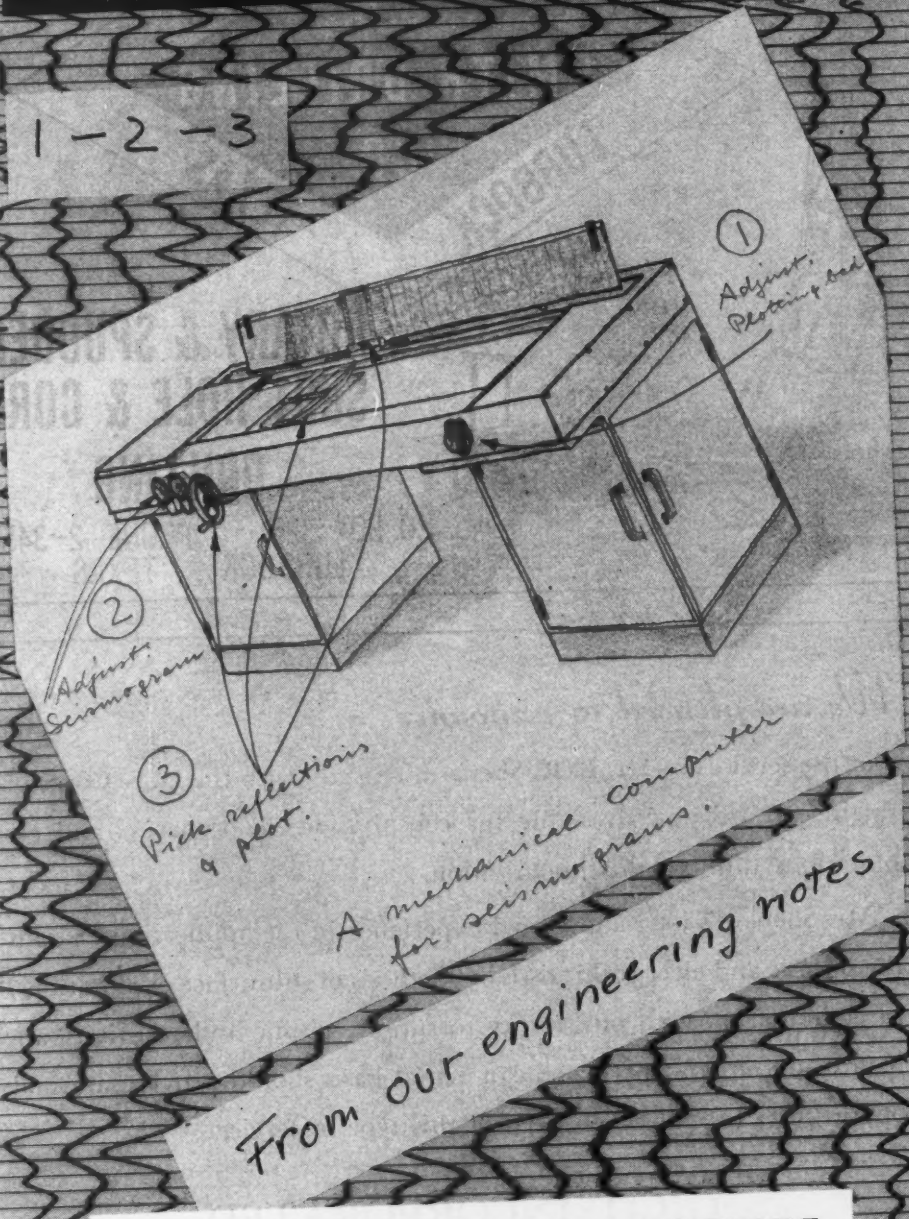

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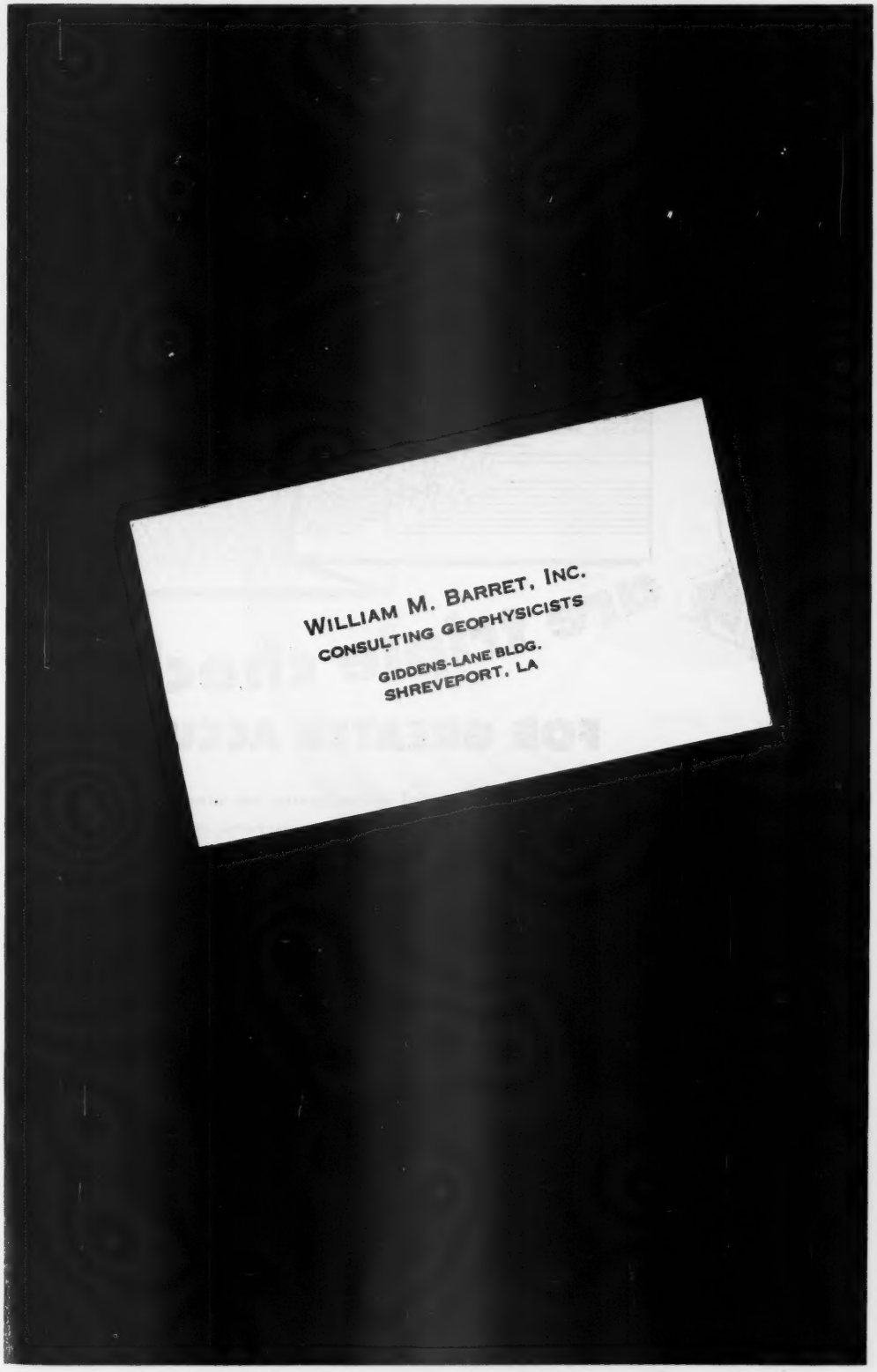
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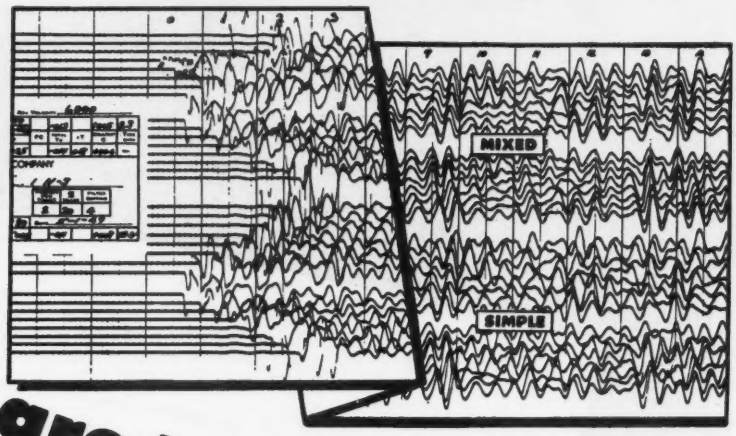

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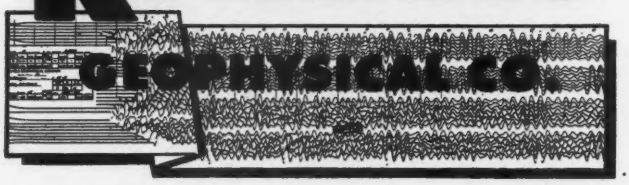

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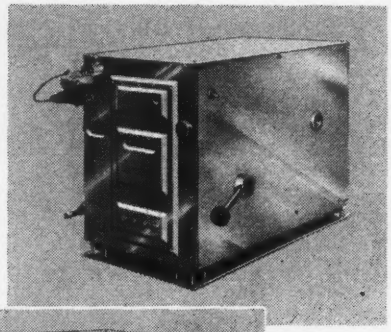
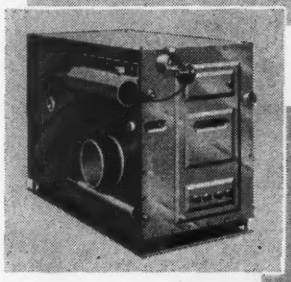
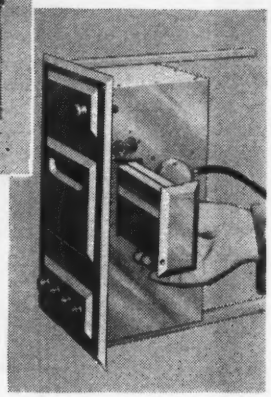


Right-hand View of Geo-Logger showing powered reel control handle.



Left-hand View of the Geo-Logger. Note the electrode and its mounting.



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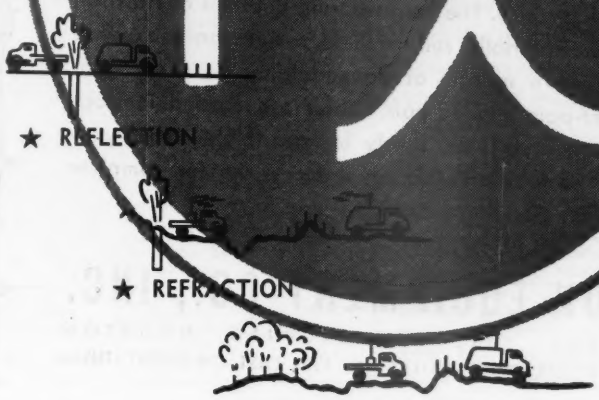

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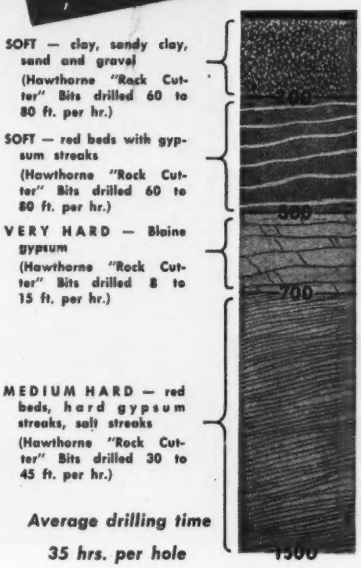
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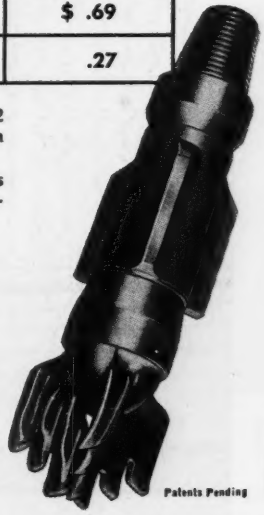

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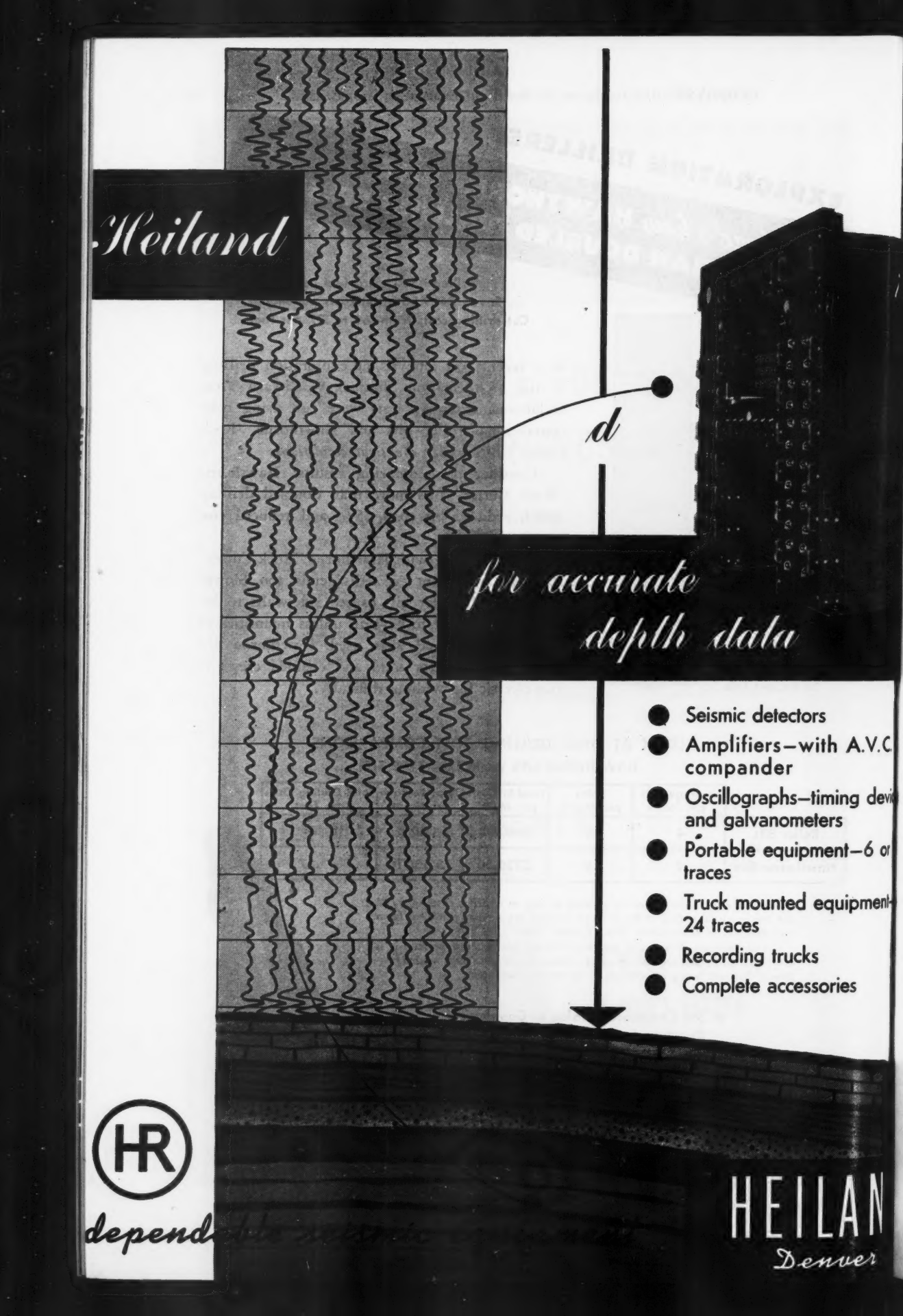
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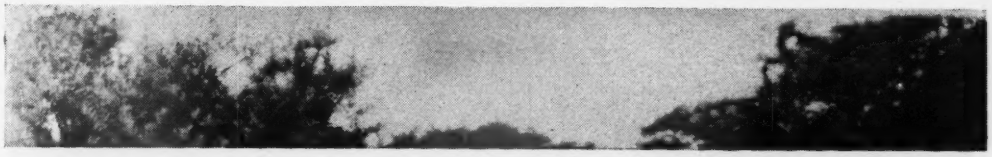

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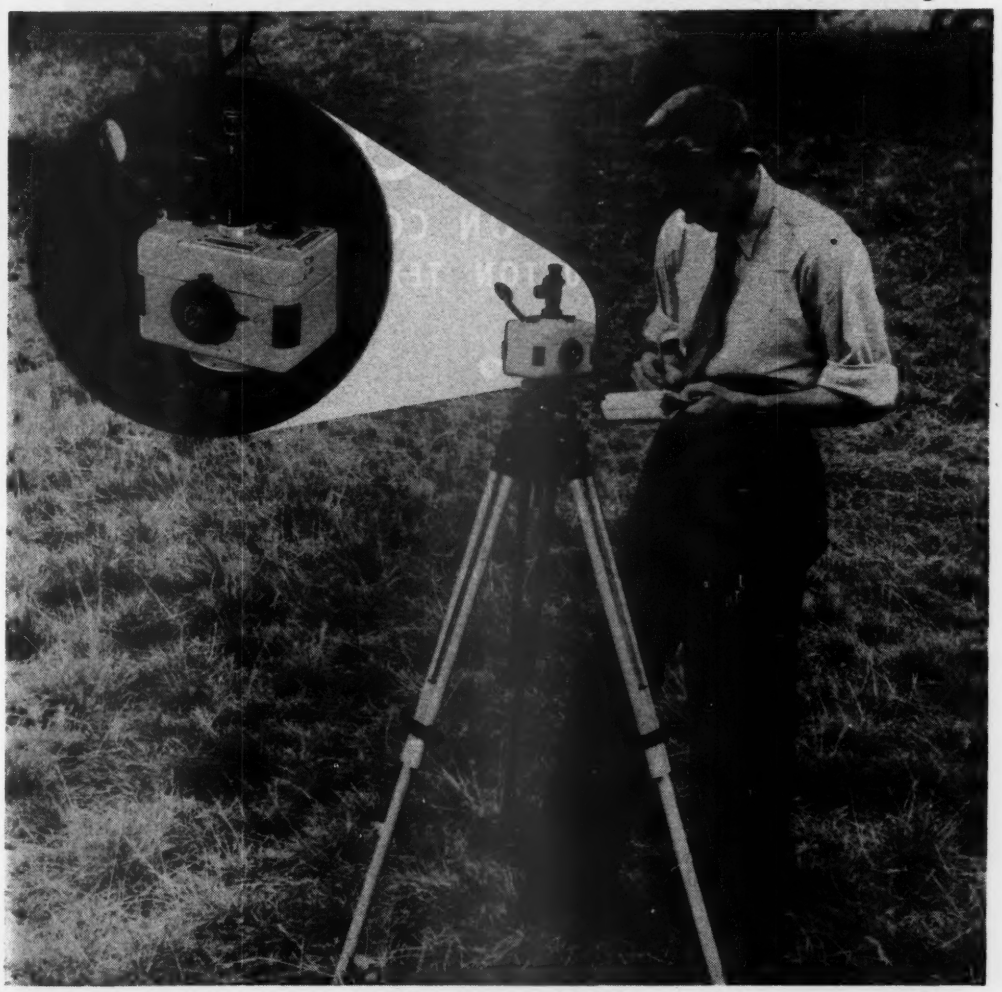

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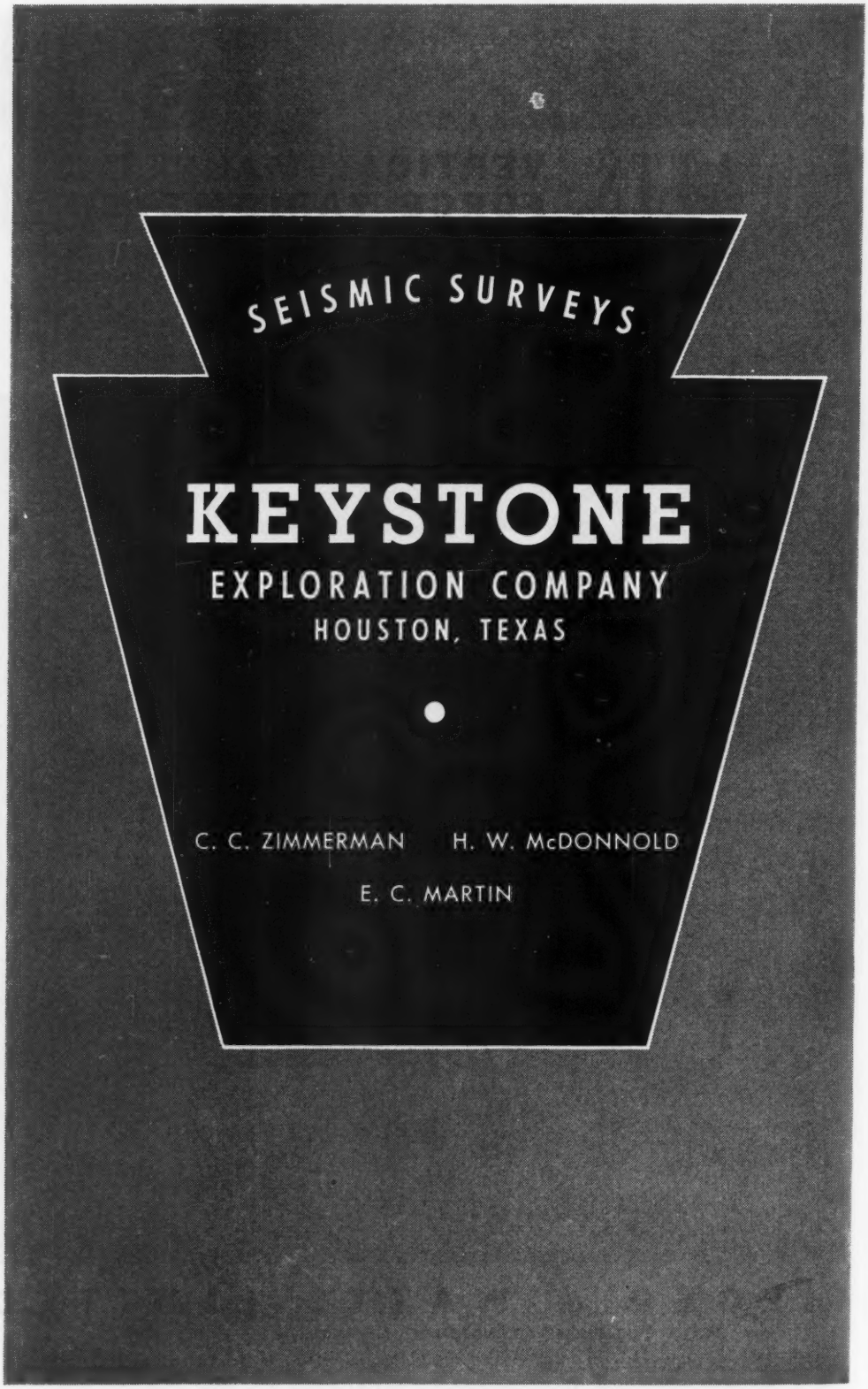
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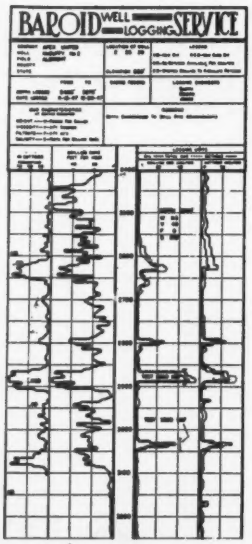

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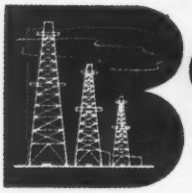

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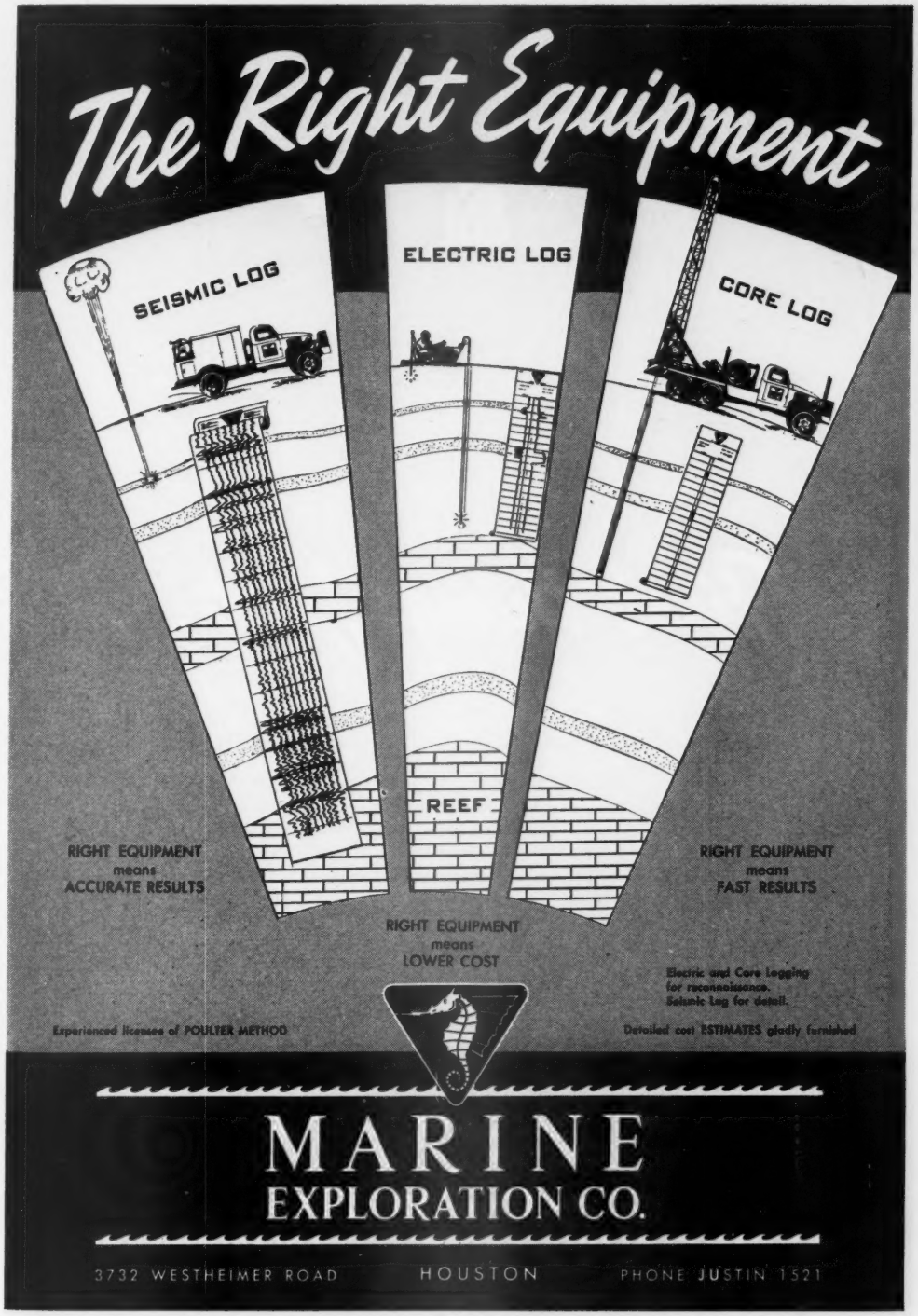
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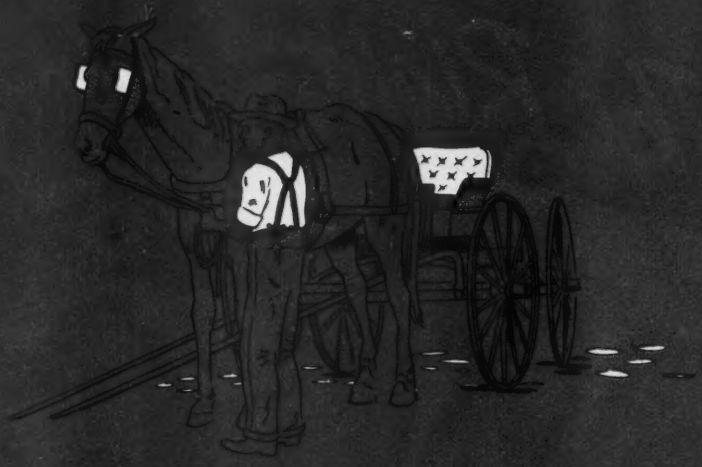

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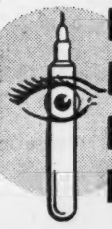

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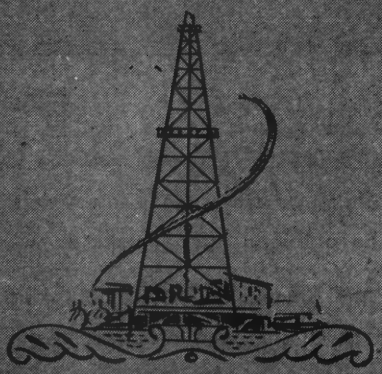

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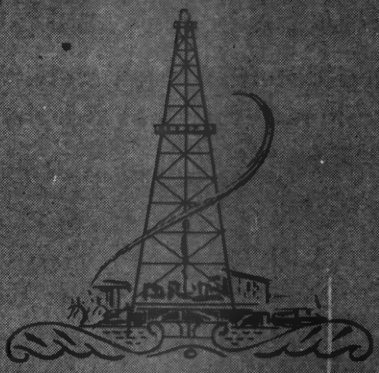

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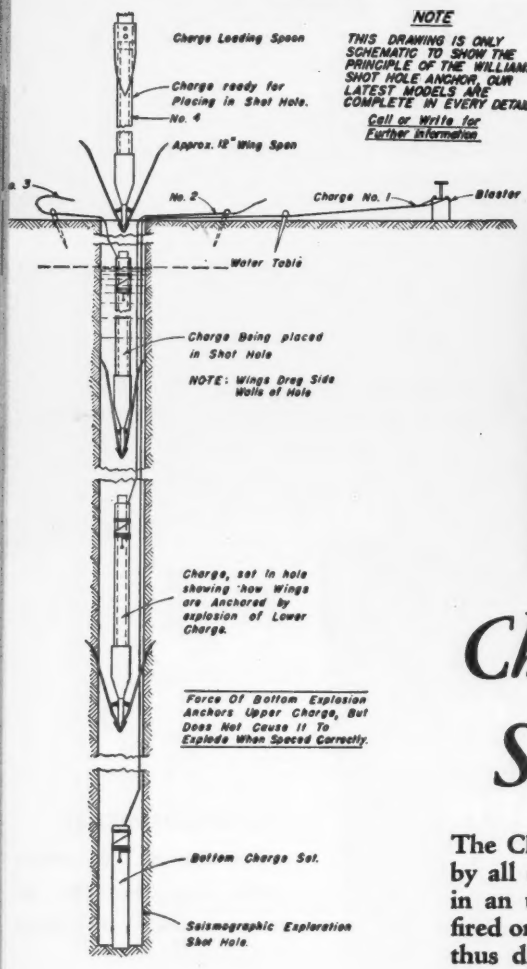
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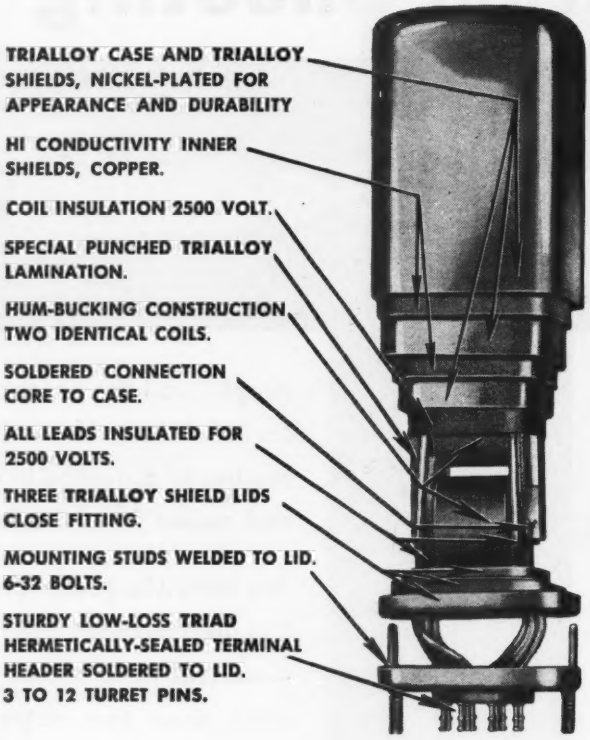
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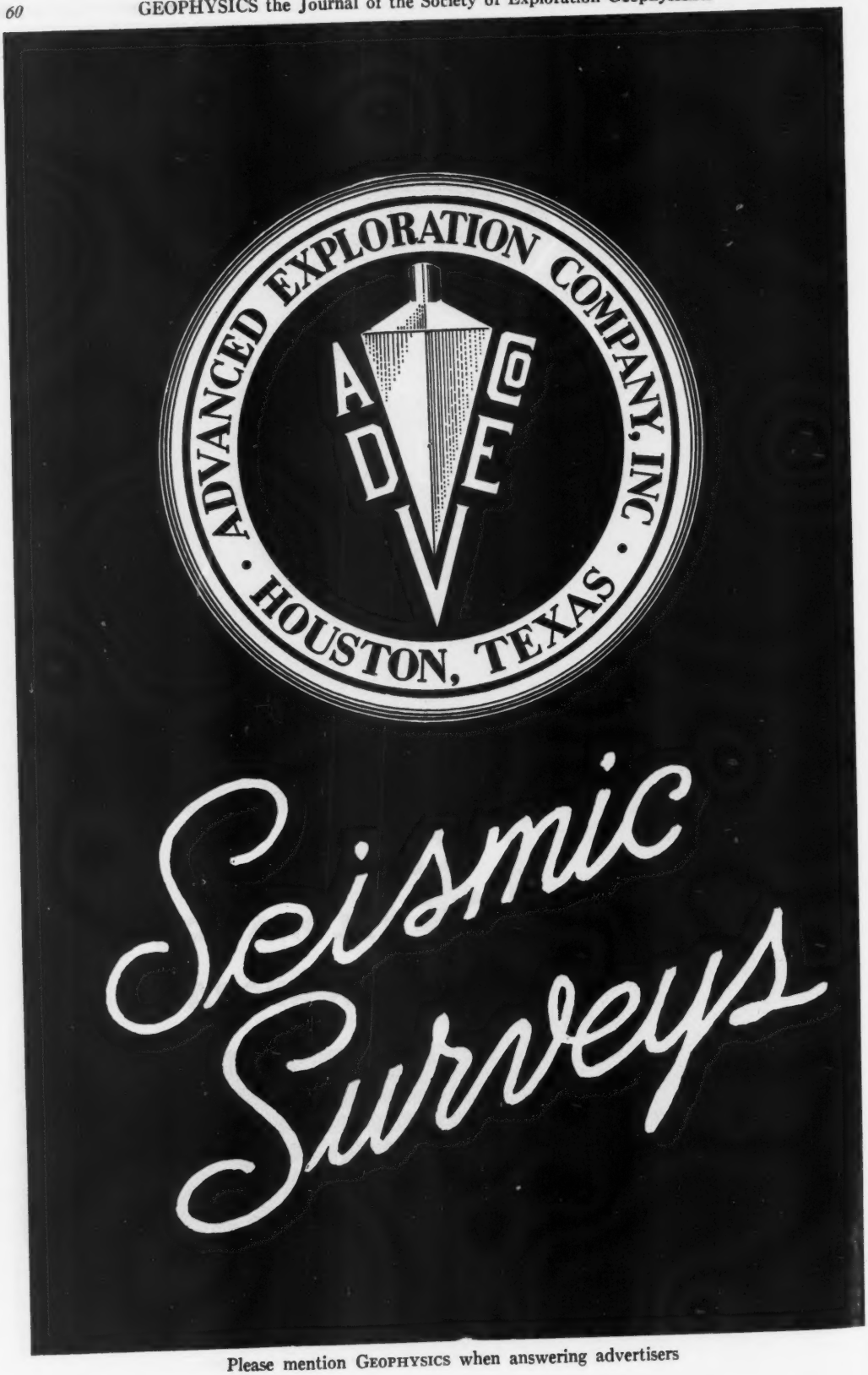
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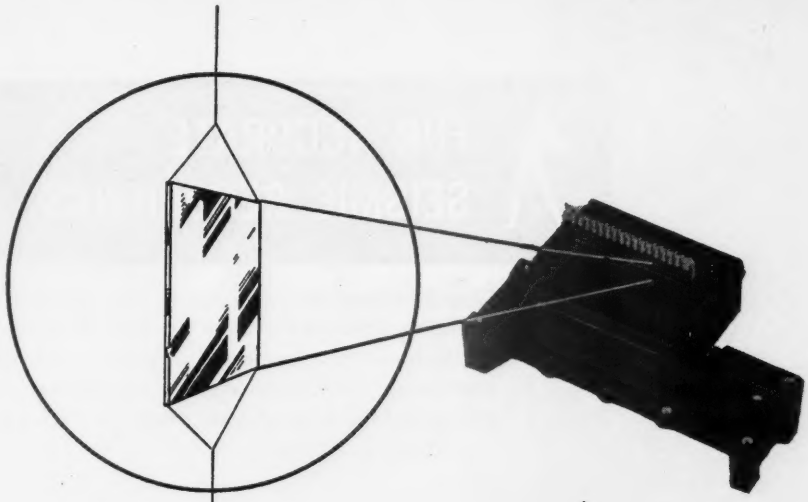

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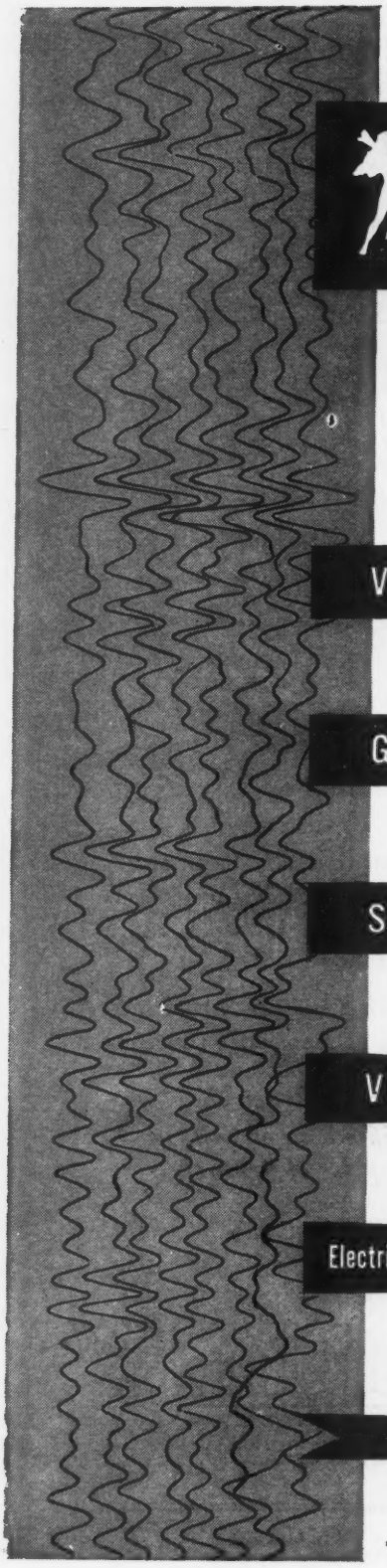

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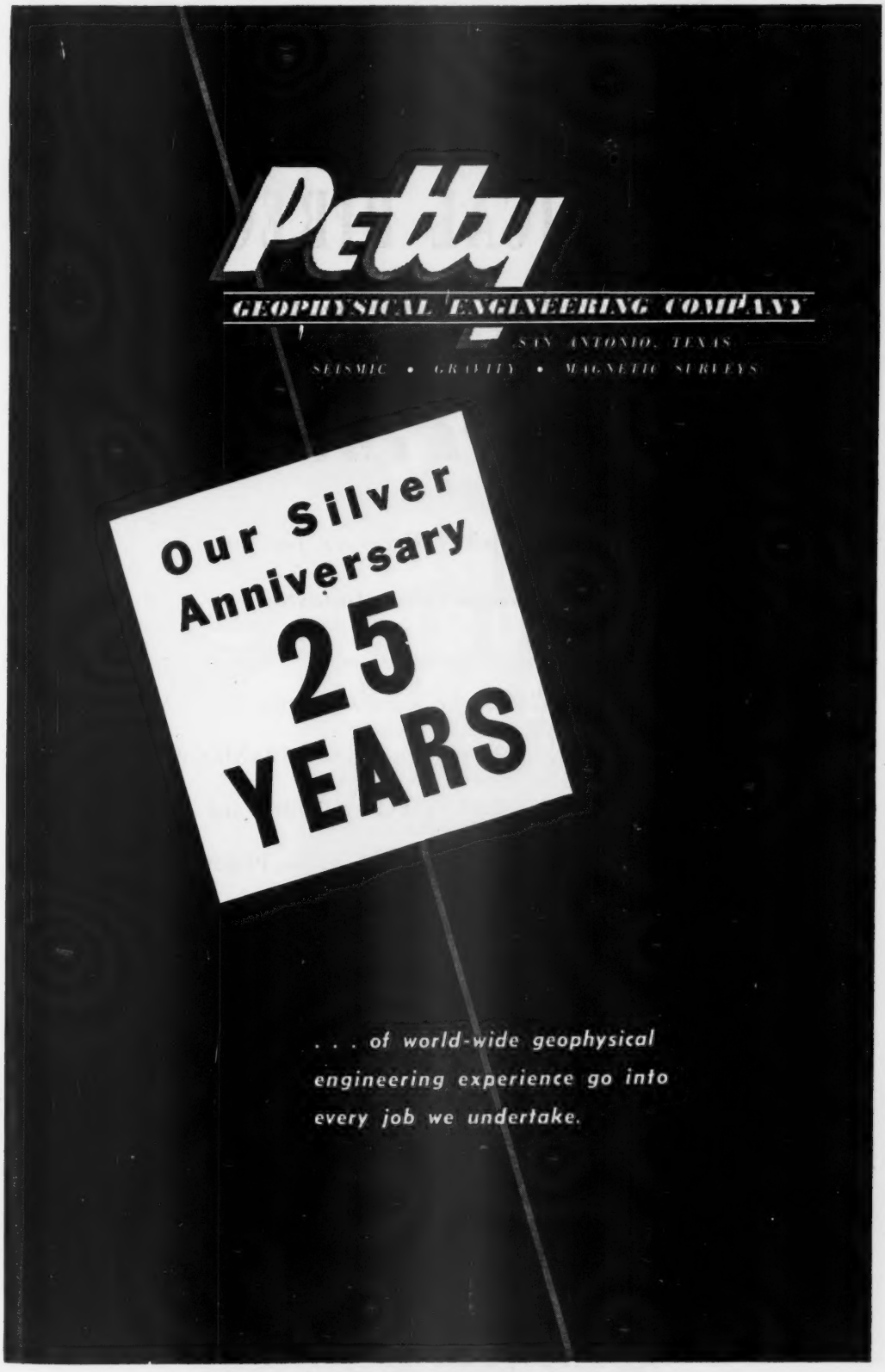
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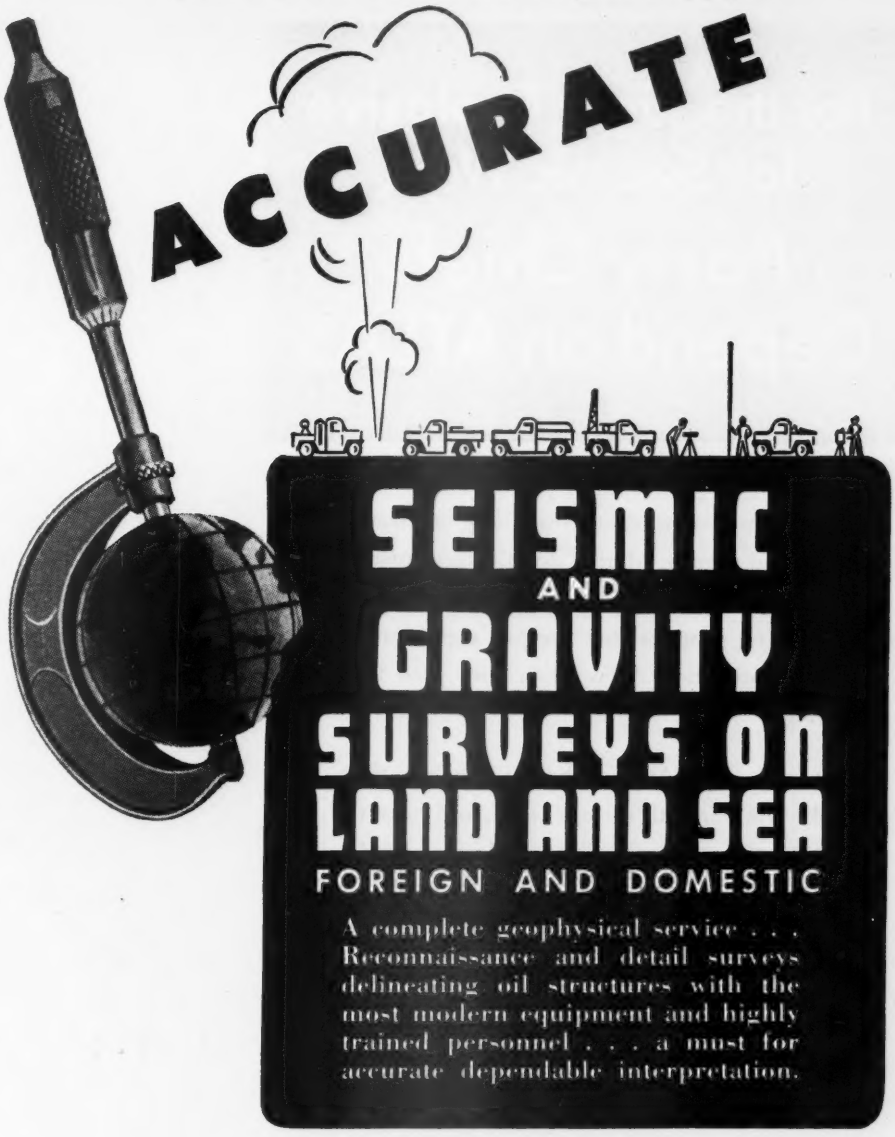
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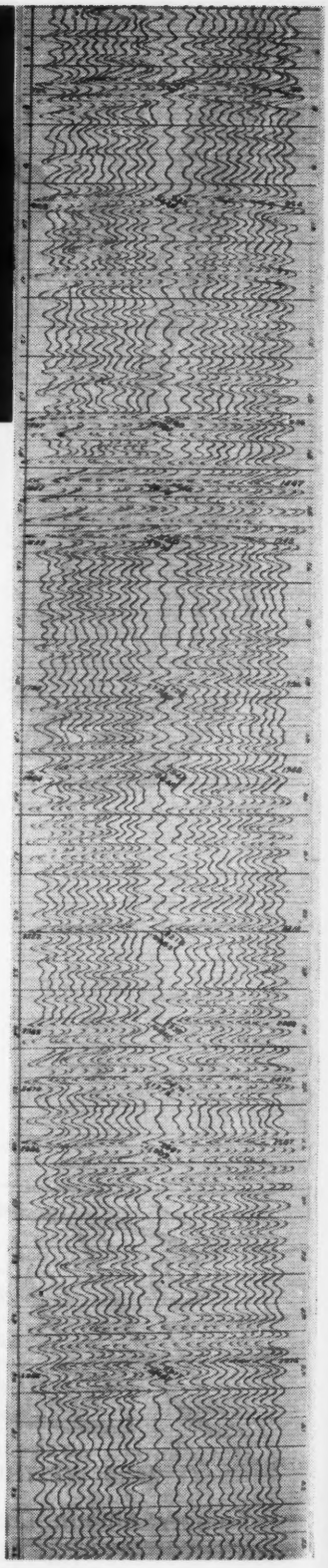

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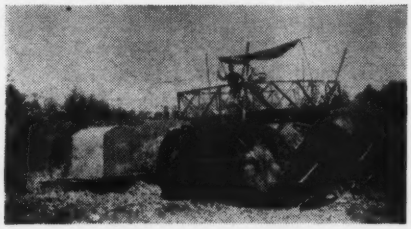

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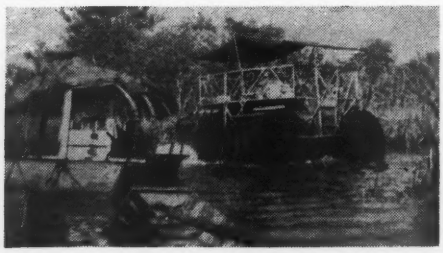

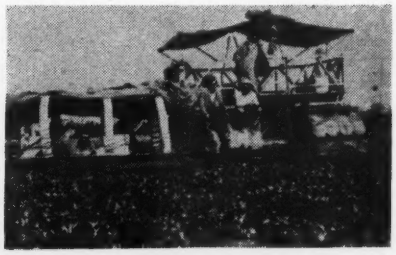

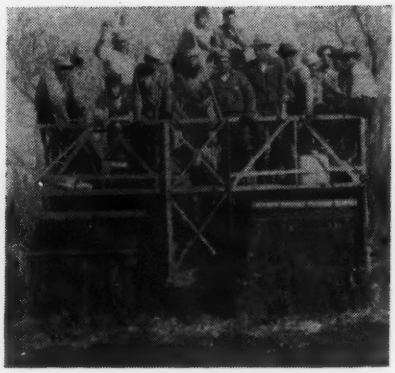

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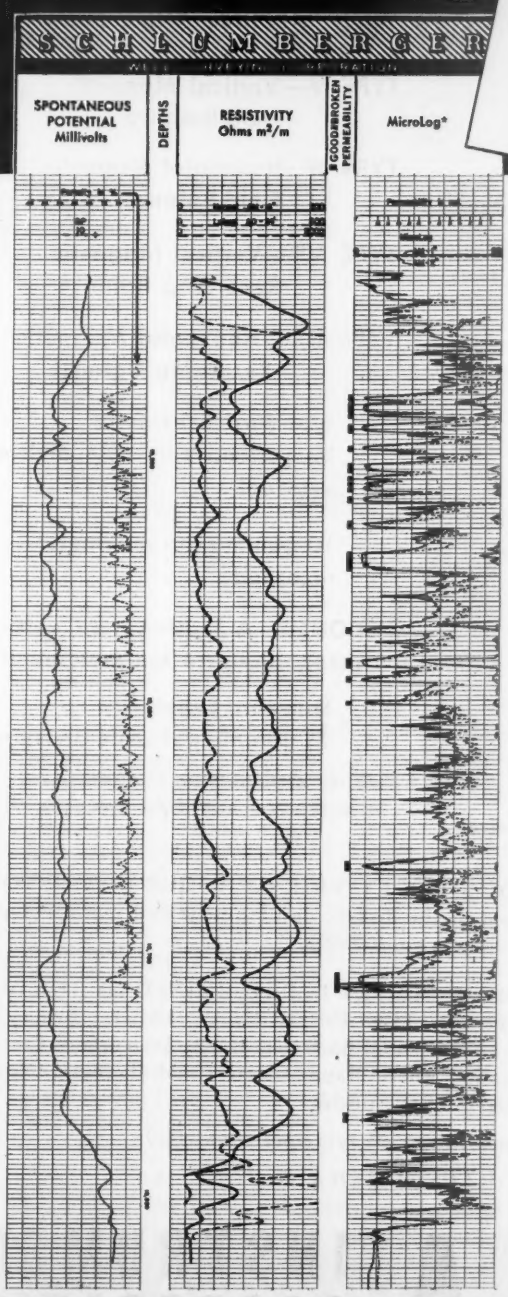

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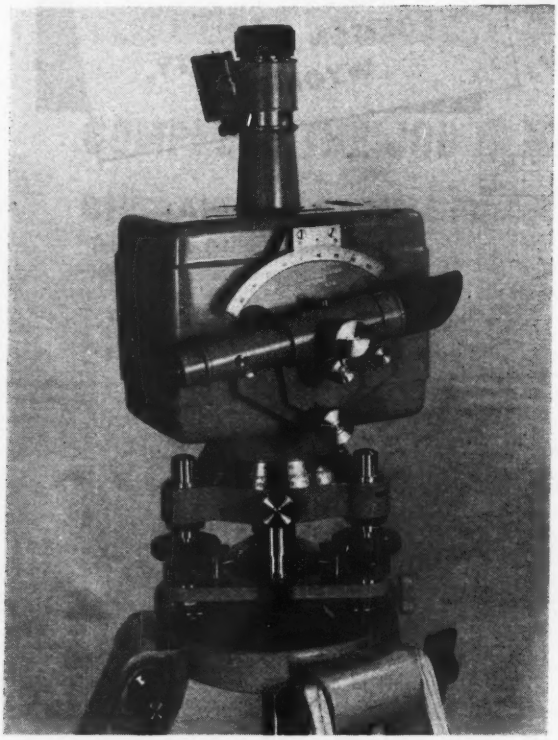

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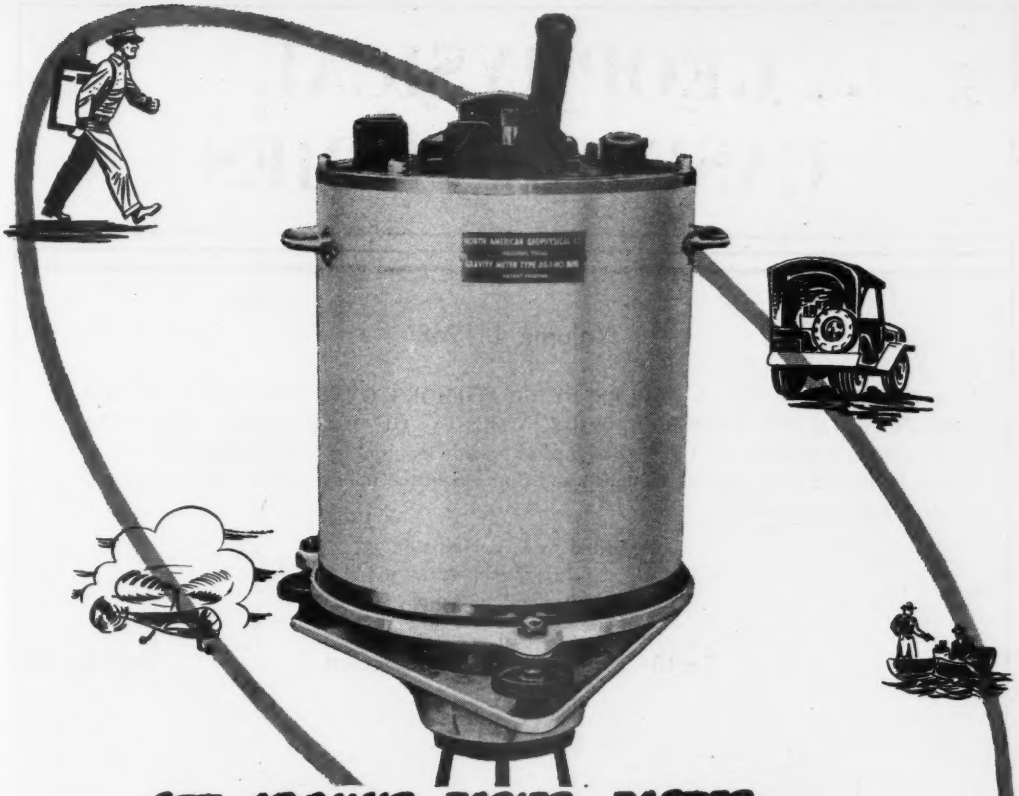

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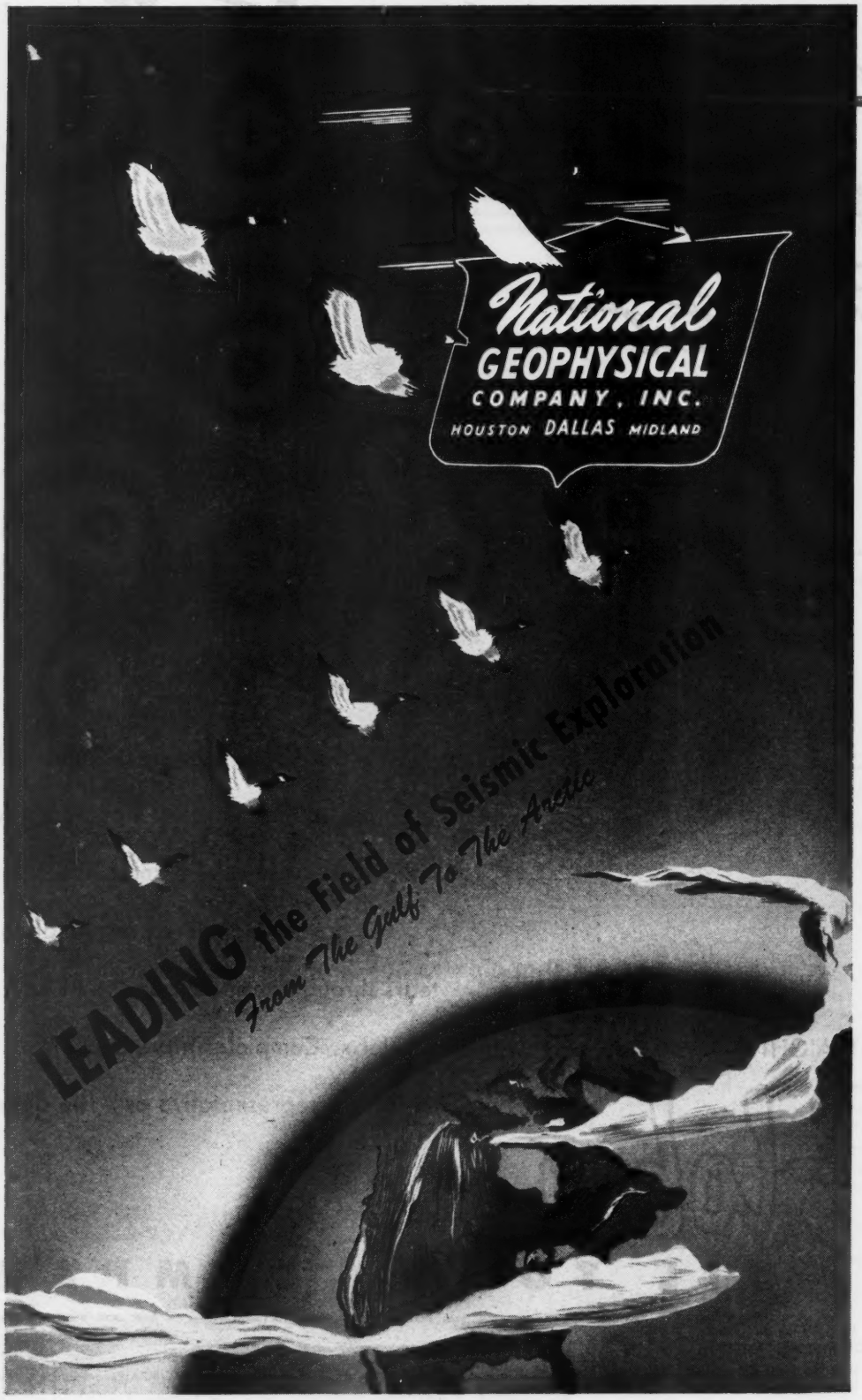
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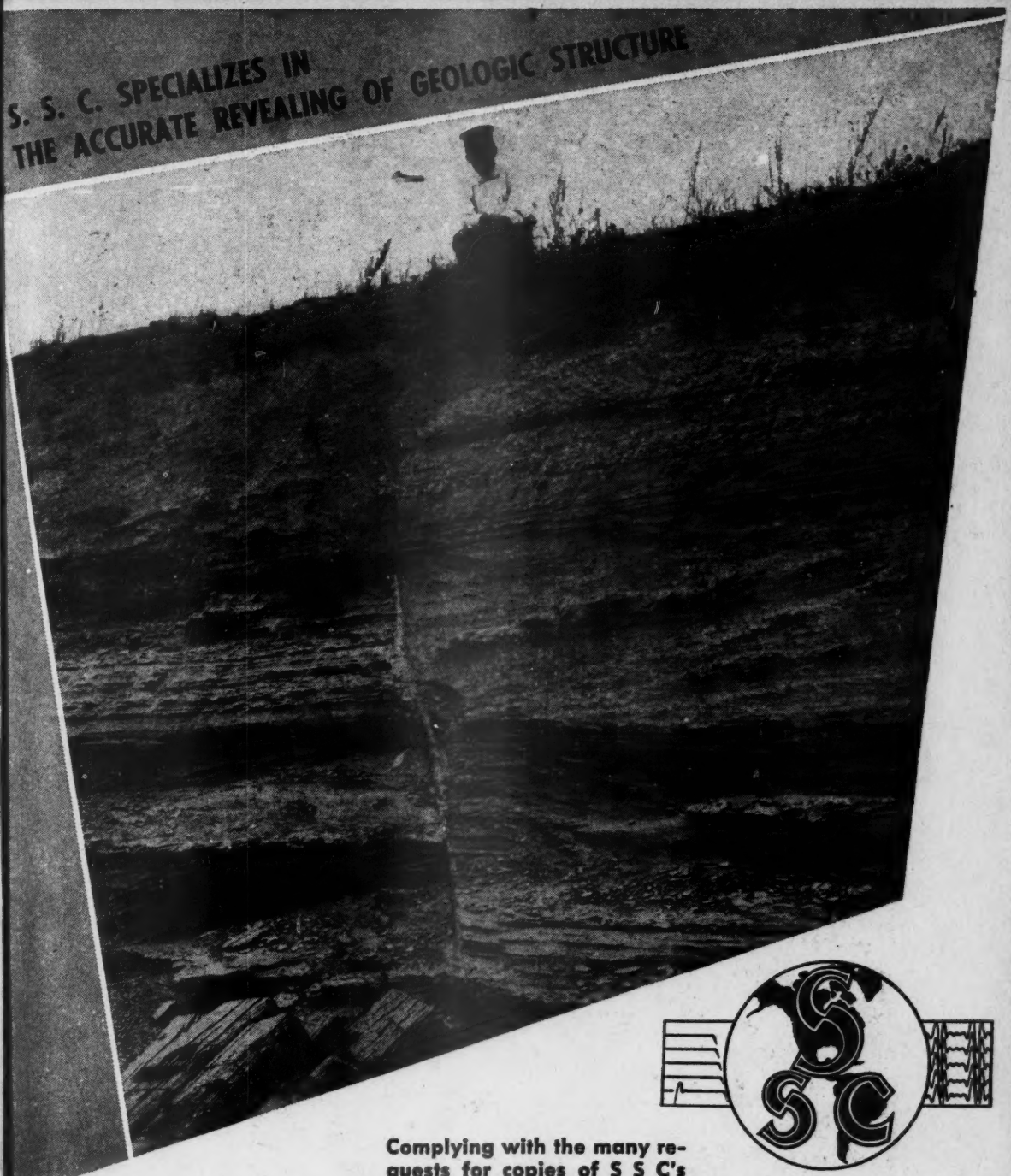

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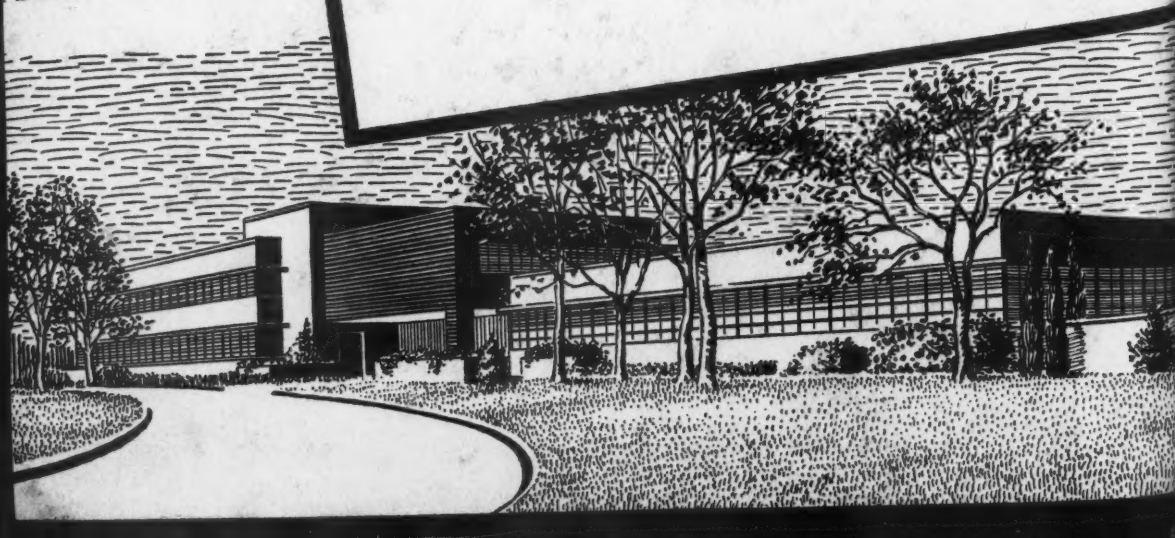
Success in finding oil has often been said to be based on luck and experience. We'll give experience the major credit.

Experience really means people. People who are skilled in planning operating techniques, in designing and manufacturing field equipment, and *especially in interpreting data.*

Our people at Geophysical Service, Inc., have been accumulating experience since pioneer exploration days. We can furnish what you require for your exploration program in any area in which you are interested.